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COVER: A female melittid bee, *Melitta americana*, an oligolect pollinator, foraging on flower of Large Cranberry, *Vaccinium macrocarpon*, at Centre-du-Québec, Quebec, Canada. Photo by André Payette. See pages 60–63 in this issue.

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CANADA

Taxonomic Implications of Morphological and Genetic Differences in Northeastern Coyotes (Coywolves) (*Canis latrans* × *C. lycaon*), Western Coyotes (*C. latrans*), and Eastern Wolves (*C. lycaon* or *C. lupus lycaon*)

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Way, Jonathan G. 2013. Taxonomic implications of morphological and genetic differences in Northeastern Coyotes (Coywolves) (*Canis latrans* × *C. lycaon*), Western Coyotes (*C. latrans*), and Eastern Wolves (*C. lycaon* or *C. lupus lycaon*). Canadian Field-Naturalist 127(1): 1–16.

The eastern Coyote or Coywolf (*Canis latrans* × *C. lycaon*) inhabiting northeastern North America resulted from hybridization between the expanding population of the western Coyote (*Canis latrans*) and the remnant population of Eastern Wolf (*C. lycaon*) and possibly domestic dogs (*C. lupus familiaris*) in the early 20th century. This study compares the body mass of eastern (i.e., northeastern) Coyotes, western Coyotes, and Eastern Wolves and synthesizes the recent literature to gain better insight into the taxonomic relations and differences of closely-related *Canis* species. Northeastern Coyotes (males = 16.5 kg; females = 14.7 kg) were statistically ($P < 0.0001$) intermediate in mass between western Coyotes (males = 12.2 kg; females = 10.7 kg) and Eastern Wolves (males = 28.2 kg, females = 23.7 kg), consistent with their hybrid origin, but were numerically closer to western Coyotes. Large Cohen's d (3.00–8.56),² (0.915–0.929), and Cohen's f (3.28–3.62) values indicated large effect sizes from the body mass comparisons. Eastern Wolves were 61–71% heavier than the same sex in the northeastern Coyotes, which in turn were ca. 35–37% heavier than the same sex in the western Coyotes. Alternatively, western Coyotes were 73–74% of the size of the same sex in the northeastern Coyotes, which in turn were 59–62% of the size of the same sex in the Eastern Wolves. I also attempted to relate mitochondrial DNA (mtDNA) haplotypes to body mass. Six of 17 (35.3%) adult female northeastern Coyotes captured in Massachusetts weighed ≥ 18 kg, heavier than any other described Coyote from outside northeastern North America. Mitochondrial DNA haplotypes associated with these heavy female northeastern canids were C9 = 4, C19 = 1, and C48 = 1. Body mass (kg) and mtDNA haplotype data of 53 northeastern Coyotes (males = 28, females = 25) showed no difference between haplotype and body mass for males ($P < 0.852$) or females ($P < 0.128$), suggesting that there is not a particular haplotype (e.g., C1) that is associated with the heavier animals. I propose that the most appropriate name for this hybrid animal is Coywolf (*Canis latrans* × *C. lycaon*), rather than a type of Coyote. Coywolves are distinct, being larger than any other population of Coyotes but smaller than Eastern Wolves. I propose that the 5 distinct types of *Canis* be recognized as: western Coyote, Coywolf (northeastern Coyote), Eastern Wolf (including Red Wolf *C. rufus*), Gray × Eastern Wolf hybrids ('Great Lakes' Wolves; *C. lupus* × *C. lycaon* or *C. lycaon* × *C. lupus*), and Gray Wolf (*C. lupus*). The implications for wolf recovery in the northeastern United States is discussed.

Key Words: *Canis latrans* × *C. lycaon*, northeastern Coyote, Coywolf, *Canis latrans*, Coyote, Domestic Dog, Eastern Wolf, *Canis lycaon*, *Canis lupus lycaon*, Gray Wolf, *Canis lupus*, hybridization.

Hybridization is increasingly being recognized as common in nature, having been documented in amphibians, insects, fish, birds, and especially within closely related plant species (Berger 1973; Arnold 1992; Fritz et al. 1994; Haddad et al. 1994; Parris et al. 1999; Arnold et al. 1999; Albert et al. 2006; Schierenbeck and Ellstrand 2009; Meyerson et al. 2010). Allendorf et al. (2001) noted that hybridization is more common in fish than in other vertebrates, and hybridization in fish has been facilitated by the extensive introduction of non-native fish species worldwide. Within mammals, hybridization has rarely been documented, but canids represent a notable case of widespread interspecies mating (Wheeldon and White 2009; Wilson et al. 2009; Way et al. 2010; vonHoldt et al. 2011).

The canid currently inhabiting northeastern North America was originally described in the 1960s as being a large Coyote-like animal that is the result of hybridization with wolves and dogs (Lawrence and Bossert 1969; Silver and Silver 1969; Lawrence and Bossert 1975). This animal has been variously called coydog, eastern Coyote, Tweed Wolf, brush Wolf, northeastern Coyote, Coyote, new Wolf, and Coywolf, and it has scientifically been described as *Canis latrans* var. (Lawrence and Bossert 1969; Silver and Silver 1969; Lawrence and Bossert 1975; Parker 1995) and as *Canis latrans* × *C. lycaon* (Way et al. 2010; Wheel-don et al. 2010a).

It is now generally accepted that northeastern Coyotes formed in the early 1900s (Hilton 1978; Parker 1995;

Wheeldon et al. 2010a) in southern Ontario through hybridization between colonizing Coyotes (*Canis latrans*) from the west and remnant populations of Eastern Wolves (*C. lycaon*) (Wilson et al. 2000, 2003, 2009; Rutledge et al. 2012a, 2012b) or *C. lupus lycaon* (a subspecies of Gray Wolf) (Nowak 2002; vonHoldt et al. 2011). The hybrid was originally called the Tweed Wolf (Kolenosky and Standfield 1975; Wilson et al. 2009).

Recent research indicates that the medium-sized Eastern Wolf (Rutledge et al. 2010b; Chambers et al. 2012; Rutledge et al. 2012a, 2012b) was probably the original species native to northeastern North America, with potential influence from Gray Wolves (*Canis lupus*) (or their hybrids) from the north (Kyle et al. 2008; Wilson et al. 2009; Fain et al. 2010; Mech 2010; Chambers et al. 2012; Wheeldon and Patterson 2012), but see the discussion in vonHoldt et al. (2011) for an alternate interpretation. In addition, a new theory (vonHoldt et al. 2011) (also see Wheeldon and Patterson

2012) holds that domestic dogs (*C. lupus familiaris*) contributed ~9% to the genetic composition of the northeastern Coyote (previous genetic studies detected no dog influence (Way et al. 2010) or insignificant amounts (Kays et al. 2010)).

Way (2007a) noted that body mass is a useful index to gauge size differences among regions or species because this metric is more commonly reported in the literature than other measurements, such as body length or cranial measures. Furthermore, MacNulty et al. (2009) found that body mass in Gray Wolves ($n = 304$) was strongly correlated with chest girth, body length, and height, indicating that mass is a valid index of overall size. Thus, a large sample of body masses from different regions should give a good approximation of morphological differences in closely related canid species (or hybrids).

In the past 75 years, northeastern Coyotes have colonized northeastern North America (Figure 1) east

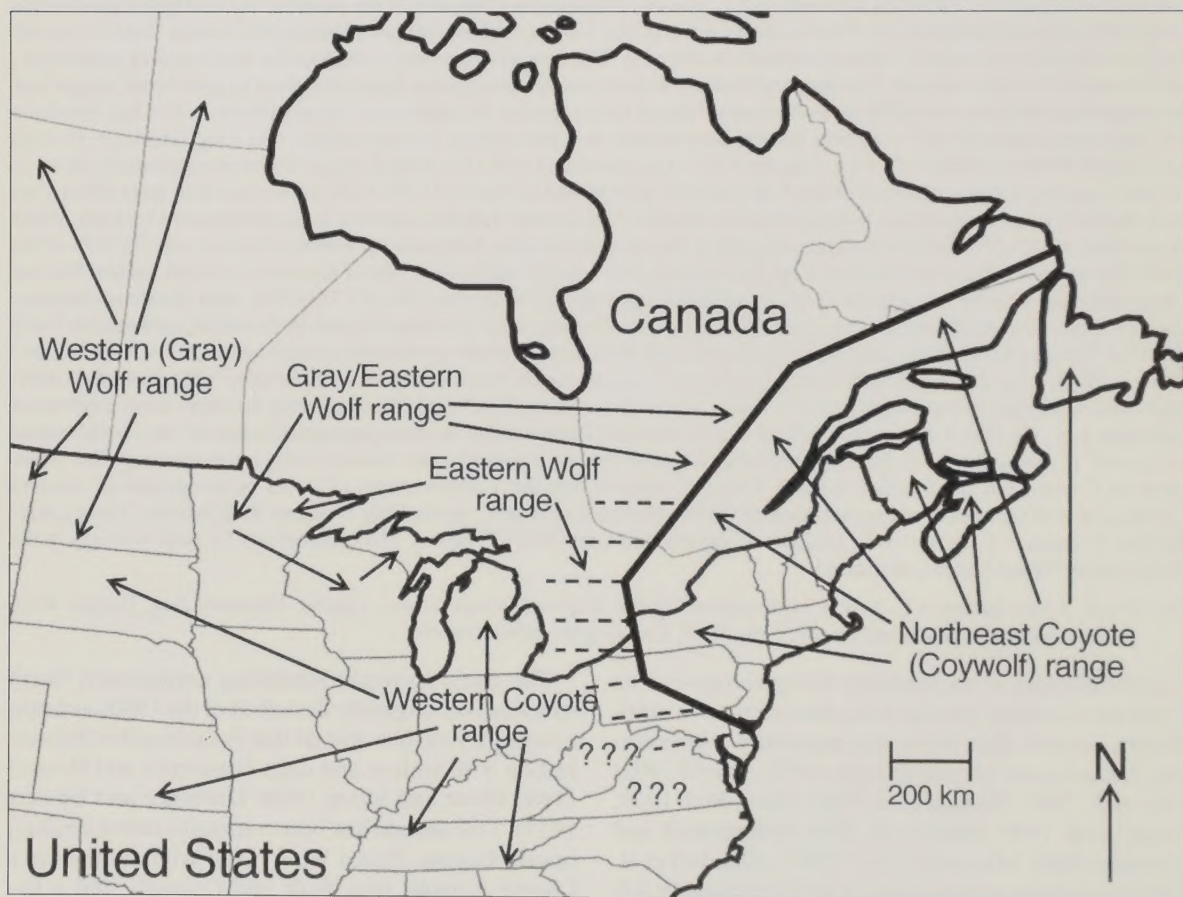


FIGURE 1. Approximate regions where various contemporary *Canis* in North America can be found, focusing on northeastern Coyote/Coywolf range. Dashed lines (e.g., southern Ontario, western Pennsylvania) denote the probable zone of hybridization between the northeastern Coyote (*Canis latrans* × *C. lycaon*) and the Eastern Wolf (*C. lycaon* or *C. lupus lycaon*) and between the western Coyote (*C. latrans*) and the northeastern Coyote. Question marks and dashed line at the southern edge of the range of the northeastern Coyote reflect uncertainty in the mid-Atlantic United States about where the range of the northeastern Coyote ends and the southern wave of expansion by the western Coyote continues (Kays et al. 2010; Bozarth et al. 2011). Boundaries should not be considered static, as there is hybridization between canids at the edges of their respective ranges (see text). Thus, rather than sharp lines separating taxa, boundaries should generally be thought of as intergrade zones of variable width (Chambers et al. 2012).

of 80° west longitude from western Pennsylvania and New Jersey in the United States to southern Ontario and the Maritime provinces in Canada. Much controversy continues to surround the taxonomic nature of this animal (e.g., see Chambers 2010 vs. Way et al. 2010). Mech (2010, page 134) noted that no one has attempted to correlate wolf (or canid) genetics with morphology, and Mech and Paul (2008) proposed that, because both the taxonomic descriptions and the mitochondrial DNA (mtDNA) haplotype assessments recognized two types of wolves (i.e., Eastern Wolves and Gray Wolves) in Minnesota, a correlation might be found between morphology and genetics. Subsequently, Kays et al. (2010) compared northeastern Coyote skull and mtDNA characteristics to those of other *Canis* populations. Wheeldon and Patterson (2012) differentiated hybridized wolves and coyotes in northeastern Ontario through genetic and morphological analysis but did not directly correlate the two variables. Similarly, Benson et al. (2012) characterized spatial genetic and morphologic structure of wolves and coyotes around Algonquin Park in Ontario and compared mass to *Canis* type but did not explicitly correlate mass to DNA haplotypes within a given *Canis* type.

Following the analysis by Thurber and Peterson (1991) of Coyote body size, Way (2007a) provided a comprehensive review of the size differences of Coyotes throughout North America. However, Way (2007a) did not compare the weights of the Coyote and the Eastern Wolf or compare their genetics (Eastern Wolf weights and genetics are rarely reported in the literature) (Mech and Paul 2008). Therefore, the objectives of this paper were to add to the knowledge of northeastern Coyote systematics by (1) conducting a comparison of northeastern Coyote body mass to those of both western Coyotes and Eastern Wolves, the putative parental species; (2) comparing northeastern canids mtDNA haplotypes with mass; and (3) reviewing the literature and describing northeastern Coyotes (Coywolves) as the 5th major *Canis* grouping in North America.

Most of the recent reviews on eastern North American *Canis* have focused on Eastern Wolves and have concluded that the Eastern Wolf is a distinct species (e.g., Fain et al. 2010; Mech 2010, 2011; Chambers et al. 2012; Rutledge et al. 2012a). However, there has also been an abundance of recent papers on Coyote genetics in eastern North America (e.g., Chambers 2010; Kays et al. 2010; Way et al. 2010; Wheeldon et al. 2010a; Bozarth et al. 2011), and I therefore attempt to synthesize these papers. Lastly, I discuss the implications of Coyote taxonomy and management in northeastern North America with regards to the recovery of the Eastern Wolf in the northeastern United States, similar to the discussion in Wheeldon and Patterson (2012, page 1229).

Methods

Body mass comparisons

I reviewed the literature to compare the body mass of northeastern Coyotes, Coyotes from areas outside

northeastern North America, and Eastern Wolves using previously published data from Way (2007a) for Coyotes, from Theberge and Theberge (2004, pages 19–24) for Eastern Wolves (including three Red Wolf (*Canis rufus*) populations from both the historical ($n = 2$) and current ($n = 1$) North Carolina range), and from any additional papers discovered reporting Coyote and Eastern Wolf mass (Appendix 1).

Although Chambers et al. (2012) recommended that Eastern Wolves and Red Wolves be treated as distinct but closely related species, I include Red Wolf values in the Eastern Wolf category (Appendix 1) because of the genetic and morphological similarity of the two putatively North American evolved species (Theberge and Theberge 2004; Rutledge et al. 2010b, 2012a, b; Wilson et al. 2000, 2009). Mech (2010) summarized genetic studies and deduced that most of Minnesota is home to hybrid Gray \times Eastern wolves. For this study, I retained samples from extreme northeastern Minnesota (Van Ballenberghe 1977) (cf. Mech and Paul 2008), as those were taken where Mech believed the highest content of Eastern Wolf resided and fell within the range of the values reported by Theberge and Theberge (2004) (Appendix 1).

All studies included in Appendix 1 report ≥ 10 individuals (of both sexes) from a given locale and include only adults (≥ 2 years old), similar to the analysis by Way (2007a).

Comparing northeastern canids mtDNA haplotypes with mass

Previous studies have classified the three main mitochondrial DNA haplotypes found in northeastern Coyotes as C1 (Eastern Wolf derived), C9 (eastern-specific haplotype that groups with Coyote haplotypes but is mainly found in Eastern Wolves and northeastern Coyotes; it has also been found in low frequency in Great Lakes states and mid-Atlantic region coyotes) (Wheeldon et al. 2010b, Bozarth et al. 2011), and C19 (western Coyote derived) (Kays et al. 2010; Rutledge et al. 2010b; Way et al. 2010; Wheeldon et al. 2010a; Rutledge et al. 2012b). Using this information, I report the body mass of large adult (≥ 2 years old) female northeastern Coyotes ≥ 18 kg captured in conjunction with a radio-monitoring study in Massachusetts (Way 2007b) and compare mitochondrial haplotypes in these females using the samples reported by Way et al. (2010).

I also correlated the mean body mass of adult and yearling northeastern Coyotes of each associated mtDNA haplotype reported from Massachusetts using data from Way (2007a) and Way et al. (2010). Unlike in the comparisons of body mass among regions, yearlings (which are technically full-grown animals) were retained here to increase sample size for statistical testing.

Statistical analyses

Analysis of variation (ANOVA) (SPSS Inc., Chicago, Illinois) was used to compare the mass of the three

groups/species of canids. The individual study or population of canids was considered to be the sampling unit. ANOVA tests were conducted separately for male and female canids. Tukey’s Honestly Significant Different (HSD) post-hoc tests were conducted when significant ($P < 0.05$) differences were detected in ANOVA.

I also used ANOVA to test for differences among the various haplotypes for both males and females, and Tukey’s HSD tests were used when significant ($P < 0.05$) differences were detected in ANOVA.

Effect size is a term used to describe a family of indices that measures the magnitude of a treatment effect (Kotrlik and Williams 2003). Effect size is different from significance tests, because effect size focuses on the meaningfulness of the results and allows for comparison between studies (Cohen 1988; Kotrlik and Williams 2003). I calculated the effect size of body mass comparisons using the following measures:

- (1) Cohen’s d and effect size r using the online program (<http://www.uccs.edu/~faculty/lbecker>), where mean body mass and standard deviation for a given canid were compared to the mass and standard deviation of a second canid (Table 1). A small effect size for Cohen’s $d = 0.2$, a medium effect = 0.5, and a large effect = ≥ 0.8 (Kotrlik and Williams 2003).
- (2) Cohen’s f , after first calculating η^2 . This required calculating:
 - (A) $\eta^2 = SS_{\text{between}} / SS_{\text{total}}$ (SS = sum of squares calculated from ANOVA table); and
 - (B) Cohen’s f = square root of $\eta^2 / (1 - \eta^2)$. A small effect size for Cohen’s $f = 0.10$, a medium effect = 0.25, and a large effect = ≥ 0.40 (Kotrlik and Williams 2003).

Results

Body mass comparisons

Body mass (mean and standard deviation) of western Coyotes ($n = 18$ populations) were as follows: males = 12.2 kg (SD 1.1), females = 10.7 kg (SD 1.0);

northeastern Coyotes ($n = 17$): males = 16.5 kg (SD 1.5), females = 14.7 kg (SD 1.5); and Eastern Wolves ($n = 6$): males = 28.2 kg (SD 2.6), females = 23.7 kg (SD 1.9) (Figure 2) (Appendix 1). ANOVA of the three groups of canids revealed significant differences for both males ($F_{2,37} = 242.2, P < 0.0001$) and females ($F_{2,35} = 187.9, P < 0.0001$). All pair-wise comparisons (e.g., northeastern to western Coyotes, Eastern Wolves to both Coyote groups) were significant ($P < 0.0001$).

These data can be interpreted as showing that northeastern Coyotes are statistically intermediate in size between western Coyotes and Eastern Wolves, although numerically closer to western Coyotes (Figure 2). Although the largest population of northeastern Coyotes almost approached the smallest Eastern Wolves, there were individual northeastern Coyotes not shown in Figure 2 that overlapped (i.e., 22–25 kg range) the smaller Eastern Wolves (Appendix 1). Because northeastern Coyotes were numerically closer to western Coyotes than to Eastern Wolves (Figure 2) (Appendix 1), the largest western Coyotes approached the smallest northeastern Coyotes. For instance, female northeastern Coyotes were 20.5% larger than male western Coyotes while female Eastern Wolves were 43.6% larger than male northeastern Coyotes.

Effect size was robust for all calculations and comparisons (Table 1). In practical biological terms, adult male Eastern Wolves were on average 1.71 times (71%) heavier than male northeastern Coyotes, which in turn were ca. 1.35 times (35%) heavier than adult male western Coyotes. Or put another way, adult male western Coyotes were 74% of the size of male northeastern Coyotes, which in turn were 59% of the size of male Eastern Wolves. Similarly, adult female Eastern Wolves were on average 1.61 times (61%) heavier than female northeastern Coyotes, which in turn were ca. 1.37 times (37%) heavier than adult female western Coyotes. Adult female western Coyotes were 73% of the size of female northeastern Coyotes, which in turn were 62% of the size of female Eastern Wolves.

TABLE 1. Effect size variables comparing the body mass of three *Canis* in North America. The square of the r value is the percentage of variance in the dependent variable that is accounted for by membership in the independent variable groups. Effect size r values are typically presented rather than r^2 .

Comparison	Cohen’s d	Effect size r	r^2	η^2	Cohen’s f
Males					
Western Coyote and northeastern Coyote	3.27*	0.853	0.727	0.929	3.62*
Western Coyote and Eastern Wolf	8.02*	0.970	0.941		
Northeastern Coyote and Eastern Wolf	5.51*	0.940	0.884		
Overall (from ANOVA)					
Females					
Western Coyote and northeastern Coyote	3.14*	0.843	0.711	0.915	3.28*
Western Coyote and Eastern Wolf	8.56*	0.973	0.947		
Northeastern Coyote and Eastern Wolf	5.26*	0.935	0.874		
Overall					

* Large effect size based on Kotrlik and Williams (2003).

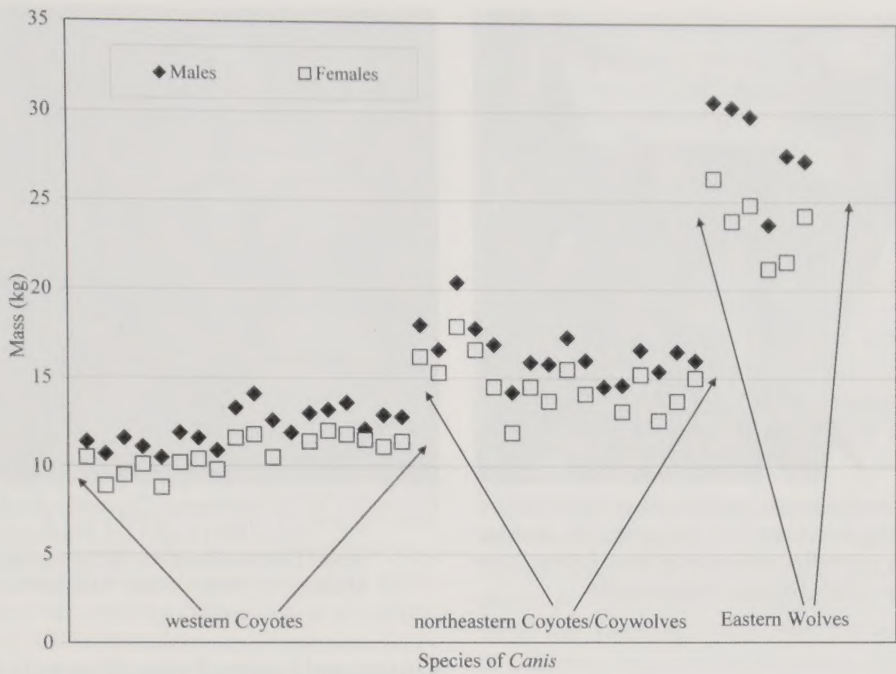


FIGURE 2. Ranges of average body mass (kg) of western Coyote (*Canis latrans*), northeastern Coyote/Coywolf (*C. latrans* × *C. lycaon*), and Eastern Wolf (*C. lycaon* or *C. lupus lycaon*) populations.

Comparing northeastern canids mtDNA haplotypes with mass

I also obtained body mass (kg) and mtDNA haplotype data for 53 northeastern Coyotes (males = 28, females = 25) from Massachusetts. Six of 17 (35.3%) radio-collared female northeastern Coyotes captured weighed ≥18 kg. Haplotypes associated with these heavy females were as follows: C9 = 4, C19 = 1, C48 (western Coyote derived) = 1. However, there was no difference between haplotype and body mass (mean (kg) and standard deviation) for males (C1: 16.9, SD 2.1, *n* = 5; C9: 16.7, SD 1.3, *n* = 13; C19: 17.2, SD 3.1,

n = 10; ANOVA: $F_{2,25} = 0.161, P < 0.852$) or females (C1: 15.2, SD 2.2, *n* = 8; C9: 17.3, SD 2.4, *n* = 11; C19: 15.5, SD 2.1, *n* = 6; ANOVA: $F_{2,22} = 2.263, P < 0.128$).

Appearance

Qualitatively, northeastern Coyotes appeared more wolf-like than Coyote-like. The appearance of 50 individual northeastern Coyotes captured in Massachusetts was as follows: white-faced animals (*n* = 10); dark brown and grizzled gray animals (*n* = 13) often described as being like a German Shepherd; light brown and blondish (*n* = 5), red (*n* = 2); or dull gray animals (*n* = 5) (Figures 3A, 3B, 3C, and 3D).



FIGURE 3A. Wild northeastern Coyote/Coywolf (*Canis latrans* × *C. lycaon*) from Cape Cod, Massachusetts, showing grizzled-gray coloration and whitish face. Photo: J. Way, January 9, 2008, Barnstable, Massachusetts.



FIGURE 3B. Wild northeastern Coyote/Coywolf (*Canis latrans* × *C. lycaon*) from Cape Cod, Massachusetts, showing reddish-yellow coloration and white face. Photo: J. Way, January 20, 2004, Barnstable, Massachusetts.



FIGURE 3C. Wild northeastern Coyote/Coywolf (*Canis latrans* × *C. lycaon*) from Cape Cod, Massachusetts, showing dark gray coloration and whitish face. Photo: Anne Middleton, 2004, Dennis, Massachusetts.



FIGURE 3D. Wild northeastern Coyote/Coywolf (*Canis latrans* × *C. lycaon*) from Cape Cod, Massachusetts, showing a robust German Shepard-like appearance. Photo: Anne Middleton, 2004, Dennis, Massachusetts.

Discussion

Morphology

Northeastern Coyotes typically weighed 13.6–18.2 kg but reached 25 kg (Figure 2) (Appendix 1) (Parker 1995; Way and Proetto 2005; Way 2007a). These weights are similar to the estimated mass of Ice Age Coyotes during the Pleistocene era, believed to be “super-sized” compared to modern Coyotes (Meachen and Samuels 2012). Chambers (2010) asserted that previous researchers (e.g., Lawrence and Bossert 1969, 1975) measuring canid morphometrics grouped northeastern Coyotes with other populations of Coyotes and hence they should continue to be called Coyotes. However, those earlier researchers acknowledged that northeastern Coyotes were larger, were a variation of the species, and proposed calling them *Canis latrans* var. until further research was conducted (Lawrence and Bossert 1969; Silver and Silver 1969).

The Eastern Wolf has only recently been described (Wilson et al. 2000, 2003) (supported by Kyle et al. 2006, 2008; Fain et al. 2010; Mech 2010; Rutledge et al. 2010b; Mech 2011; Chambers et al. 2012; Rutledge et al. 2012a). The work of earlier researchers (including Lawrence and Bossert 1969; Silver and Silver 1969; Kolenosky and Standfield 1975; Hilton 1978; Schmitz and Kolenosky 1985; Schmitz and Lavigne 1987) did not acknowledge, or know of, the presence of this smaller species of wolf, instead recognizing it as a subspecies of Gray Wolf (*C. lupus lycaon*). However, these authors (Kolenosky and Standfield 1975; Schmitz and Kolenosky 1985) recognized several forms of wolves and noted that coyotes mated with the smaller Algonquin type wolf (i.e., the Eastern Wolf).

The reanalysis of data in this paper incorporating western Coyotes, northeastern Coyotes, and Red/Eastern Wolves shows that canids in northeastern North America are statistically intermediate between western

Coyotes and Eastern Wolves (Figure 2). These results are further supported by large effect sizes (Table 1); also see Rutledge et al. (2010b) and Benson et al. (2012) for Eastern Wolf-Coyote body size comparisons. Furthermore, western Coyotes close to the range of the northeastern Coyote (i.e., in the Midwest or the Great Lakes area) are no bigger than Coyotes found elsewhere (Figure 1) (Appendix 1).

Way (2007a) noted that Coyotes from northeastern North America were so much larger than the typical reported weight for the species that they would be classified in a different size category (based on the body mass) than western Coyotes in many review studies of carnivore-sized guilds. Way (2007a) also summarized a wide range of weights reported for northeastern Coyotes. The mass of northeastern Coyotes from all sites in northeastern North America averaged higher than Coyotes elsewhere—so much so, that longitude accounted for >4 times the amount of variation in body mass than latitude. Six of 17 (35.3%) adult females captured in Massachusetts weighed ≥18 kg, a mass that to my knowledge has not been reported for western Coyotes and approaches the size of female Eastern Wolves (21–26 kg) (Appendix 1). Recent genetic analyses (Kays et al. 2010; Way et al. 2010; Wheeldon et al. 2010a) have confirmed that northeastern Coyotes are hybrids between western Coyotes and Eastern Wolves and this undoubtedly contributes to their larger, statistically intermediate size.

Comparing northeastern canids mtDNA haplotypes with mass

Four of 6 (66.7%) of the heaviest females in this study had the C9 (eastern specific) haplotype (Grewal et al. 2004; Rutledge et al. 2010b; Way et al. 2010) and individuals with the C9 haplotype had the numerically largest average value for females. None of the

heavy females carried the Eastern Wolf specific C1 mtDNA haplotype. However, caution should be used when interpreting these results because of a small, non-significant sample size. For example, a possibility exists that these large animals carrying the C9 haplotype came from the same local large-bodied female lineage reported in Way and Proietto (2005). There was only a slight difference in male weights, but males with the C19 mtDNA haplotype were the numerically heaviest males.

Since both males and females with the C1 (i.e., Eastern Wolf derived) mtDNA haplotype were not the heaviest subset of this population, there has probably been sufficient genetic exchange among northeastern Coyotes for them to be one homogenous population, as discussed in Way et al. (2010). In other words, while there are likely to be a range of sizes (since this animal recently (ca. 75–100 years ago) formed from two (Coyotes and Eastern Wolves) or possibly three (domestic dogs) parental species) (Wheeldon et al. 2010a; vonHoldt et al. 2011; Wheeldon and Patterson 2012), it has likely been long enough for this animal to have had sufficient genetic admixture where large animals would potentially carry any of the major mtDNA haplotypes. Further, since morphological differences likely do not correlate with mtDNA haplotypes (mtDNA is inherited maternally and without recombination), the presence of a particular haplotype in an individual or population may represent contemporary hybridization or historical introgression from one or more distant hybridization events. Northeastern coyotes likely experienced historical introgression (i.e., in the early 1900s) because there is little or no opportunity for ongoing (contemporary) hybridization between Coyotes and Eastern Wolves across the majority of the range of the northeastern Coyote (e.g., in most of New England; Figure 1), and the wolf DNA present in northeastern Coyotes represents that which was introgressed in the early 20th century in Ontario (Wheeldon et al. 2010a).

Ecological role of northeastern canids

Kays et al. (2010) found that northeastern Coyotes have larger skulls (up to 15% bigger than western Coyotes), which they speculated would allow them to better exploit White-tailed Deer (*Odocoileus virginianus*), consistent with other studies in northeastern North America that documented high amounts of White-tailed Deer in the diet of Coyotes (Ballard et al. 1999; Patterson and Messier 2000, 2001). Kays et al. (2010) also found significant craniodental differences in these animals that would better facilitate preying on White-tailed Deer. A greater reliance on White-tailed Deer would put the northeastern Coyote intermediate in an ecological context between the western Coyote and the Eastern Wolf (Parker 1995; Theberge and Theberge 2004). The findings of Kays et al. (2010) are similar to previous studies (i.e., Lawrence and Bossert 1969; Silver and Silver 1969) that documented that the skulls

of northeastern Coyotes were larger than those of any extant Coyote population.

Future studies should attempt to elucidate the role of the northeastern Coyote as either a mesocarnivore or an apex (top-down) carnivore (Prugh et al. 2009). No studies have documented the ability of the northeastern Coyote to kill Moose (*Alces alces*) (although the role of Eastern Wolves in limiting Moose populations is also debatable—see Theberge and Theberge 2004). It may be that northeastern Coyotes act as apex carnivores in systems dominated by White-tailed Deer (i.e., southern New England and most urbanized areas) but likely as mesocarnivores in systems dominated by Moose (e.g., northern New England).

Appearance



The observed wolf-like characteristics of northeastern Coyotes (Figures 3A, 3B, 3C, and 3D) make them appear similar to Red Wolves and Eastern Wolves (see photos in Smith 1996; Whitaker 1991, Plate 256; Theberge and Theberge 1998; Way 2007b, color plates). In addition, tracks of northeastern Coyotes measure 7.6–9.5 cm (3.0–3.75 inches) in length, which exceeds any described track measurements for western Coyotes (6.4 cm) (2.5 inches) and approaches the size of the tracks of Red Wolves (~10.2–11.4 cm) (4.0–4.5 inches) (J. Way, unpublished data) (Miller 1981; Stokes and Stokes 1986; Whitaker 1991). These 2 characteristics (i.e., appearance and track size) support the intermediate morphology of northeastern Coyotes.

Taxonomy and hybridization in eastern Canis: Eastern Wolf influence

Based on the majority of the recently published literature (Wilson et al. 2000; Nowak 2002; Wilson et al. 2003; Kyle et al. 2006, 2008; Wilson et al. 2009; Fain 2010; Mech 2010; Rutledge et al. 2010a, 2010b; Mech 2011; Chambers et al. 2012; Rutledge et al. 2012a, 2012b), I have assumed that the wolf that hybridized to form the northeastern Coyote is a North American-evolved wolf species (*C. lycaon*) that is independent of the Gray Wolf and closely related to the Coyote.

Hybridization between coyotes and wolves is limited to eastern North America, with the Eastern Wolf being a conduit of hybridization between both western Coyotes and western Gray Wolves (Table 2) (Roy et al. 1996; Wilson et al. 2000; Wheeldon and White 2009; Wilson et al. 2009; Fain et al. 2010; Kays et al. 2010; Mech 2010; Rutledge et al. 2010b; Way et al. 2010; Benson et al. 2012), with potential influence from Gray Wolves and dogs in the southeastern U.S. (Adams et al. 2003a, 2003b). The geographic extent of wolf × Coyote hybridization is consistent with the historical range of both the Eastern Wolf and the Red Wolf (Wilson et al. 2000; Nowak 2002; Wilson et al. 2003; Kyle et al. 2006; Wilson et al. 2009; Mech 2010, 2011; Chambers et al. 2012).

TABLE 2. Summary of types of *Canis* currently described in North America. As depicted in this continuum, the Eastern Wolf (*Canis lycaon* or *C. lupus lycaon*) serves as the conduit of hybridization for both the Gray Wolf (*C. lupus*) (in the western Great Lakes and southeastern Canada) and the Coyote (*C. latrans*) (in the southeastern United States and southern Ontario) and has created two hybrid types: the northeastern Coyote/Coywolf (*C. latrans* × *C. lycaon*) (no. 2) and the Gray Wolf × Eastern Wolf hybrids (*C. lupus* × *C. lycaon* and *C. lycaon* × *C. lupus*) (no. 4). See the Discussion for literature citations regarding each type, including a competing theory of canid identity and evolution (vonHoldt et al. 2011).

Body mass (smallest to largest)	Ability to hybridize
1. Western Coyote (<i>Canis latrans</i>), 8.2–13.6 kg Range: Most of North America south of the Arctic Circle excluding northeastern North America Remarks: Eastern and western coyotes meet in western Pennsylvania and New York, with relatively pure western Coyotes in Ohio	
2. Northeastern Coyote/Coywolf (<i>Canis latrans</i> × <i>C. lycaon</i>), 13.6–22.7 kg Range: Northeastern North America from southeastern Canada to the New Jersey–New York region Remark: Status of canids in the southeastern United States is still not fully established, but zones of hybridization between western Coyotes and Red Wolves are believed to occur	
3. Eastern Wolf (<i>Canis lycaon</i> or <i>C. lupus lycaon</i>), 22.7–31.8 kg Range: Formerly eastern North America from southeastern Canada to the southeastern United States; now relict populations (see text) Remarks: The Red Wolf (<i>C. rufus</i>) in the southeastern United States is included in this category	
4. Gray Wolf × Eastern Wolf hybrids (<i>Canis lupus</i> × <i>C. lycaon</i> and <i>C. lycaon</i> × <i>C. lupus</i>), 27.3–40.9 kg; “Great Lakes wolf” Range: Great Lakes region between the ranges of the Eastern Wolf and the Gray Wolf, including Minnesota, Michigan, Wisconsin, and southern Ontario around the Great Lakes	
5. Gray Wolf (<i>Canis lupus</i>), 36.4–59.1 kg Range: Western North America into eastern North America, where it hybridizes with the Eastern Wolf around the western Great Lakes region Remarks: Largest types are found in Alaska south to the Rocky Mountains	

Although the majority of scientists accept the Eastern Wolf as a distinct taxon, vonHoldt et al. (2011), using high-density single nucleotide polymorphism (SNPs) genotyping arrays, describes only the Coyote and the Gray Wolf as distinct entities in North America and treats all other types of canids (e.g., northeastern Coyote, Red Wolf, Eastern Wolf, “Great Lakes” Wolf) as hybrids with varying degrees of admixture between Coyotes and Gray Wolves. Because all members of the genus *Canis* are karyotypically identical and they interbreed, Coppinger et al. (2010) argued that the different *Canis* could be recognized as subspecies of an overall species.

However, a comprehensive review of the taxonomy of wolves in North America supports the Eastern Wolf as a distinct taxon (Chambers et al. 2012). Furthermore, in a reply to vonHoldt et al. (2011), Rutledge et al. (2012a) stated that SNPs should not be viewed as an indiscriminate replacement for other biological (e.g., body size) and complementary genetic data (e.g., mtDNA, microsatellites, Y-chromosomes) and that there was indeed compelling evidence to support the Eastern Wolf as a distinct species.

Domestic dog influence

vonHoldt et al. (2011, page 7) described the northeastern Coyote as being much more like a Coyote (82%) than a wolf (~9%) (and dog, ~9%). vonHoldt et al. (2011) also describes the Red Wolf as being more like a Coyote (75%) than a wolf (25%). The more accepted theory of the Eastern Wolf being distinct and closely related to Coyotes, however, would suggest that the degree of wolf influence found in northeastern Coyotes (and in Red Wolves) could be underestimated by vonHoldt et al. (2011). Furthermore, there is considerable evidence that Gray × Eastern Wolf hybrids (i.e., Great Lakes Wolves) and Gray Wolves do not hybridize with western Coyotes (Mech 2010; Wheeldon et al. 2010b; Mech 2011). Thus, the alternative theory or interpretation proposed by vonHoldt et al. (2011) requires confirmation that interspecific mating between western Coyotes and Gray Wolves occurs (Mech 2010).

The discovery of domestic dog DNA in northeastern Coyotes (vonHoldt et al. 2011) warrants additional research. Previously, Coyote × domestic dog interbreeding was suspected to occur only in the south-

eastern U.S. (Adams et al. 2003a). Way et al. (2010), using mtDNA and nuclear microsatellites, detected no domestic dog DNA in northeastern Coyotes and outlined reasons why Coyote \times domestic dog interbreeding probably did not occur in northeastern canids. Kays et al. (2010) found one partial sequence of a domestic dog-like haplotype (from Vermont) in 453 samples from throughout the northeast. The authors did not elaborate on this but it is possible that this animal was an F_1 Coyote \times domestic dog hybrid which might have never reproduced in the wild.

vonHoldt et al. (2011) claimed that this hybridization took place ~30 years ago (1980s), yet by that time Coyotes had already colonized most of northeastern North America (Parker 1995), making it unlikely that they repeatedly hybridized with domestic dogs once they were already well established in the region (i.e., compared to a more ancient hybridization scenario) (see Adams et al. 2003a).

Conclusions regarding hybridization in eastern Canis

With changing land use patterns, hybridization should not be viewed as a negative influence, as it may enhance the adaptive potential of both western Coyotes and Eastern Wolves, allowing northeastern Coyotes to more effectively exploit available resources in northeastern North America (Kyle et al. 2006), similar to what has been observed in hybrid amphibians (Parris et al. 1999) and eels (*Anguilla* spp.) (Albert et al. 2006).

Because the currently accepted view that the original species of wolf found in northeastern North America was the Eastern Wolf and not the Gray Wolf (Wilson et al. 2009; Fain et al. 2010; Mech 2010, 2011; Chambers et al. 2012; Rutledge et al. 2012a, 2012b) (although see vonHoldt et al. 2011), the northeastern Coyote (harboring Eastern Wolf genes) likely retains some of the original genetic diversity of canids from northeastern North America, even from areas where the Eastern Wolf has been extirpated (Murray and Waits 2007; Kyle et al. 2008).

Hybridization can be important for adaptive evolution when hybrid genotypes have high fitness levels (Arnold et al. 1999). Albert et al. (2006) similarly noted that natural selection may influence the relative fitness of hybrids in terms of differential survival and may therefore modulate the observed proportion of hybrids. Given that Eastern Wolves are functionally extinct in most of northeastern North America (Benson et al. 2012; Wheeldon and Patterson 2012) and northeastern Coyotes colonized the region five times faster than western Coyotes coming from south of the Great Lakes through the Ohio area (Kays et al. 2010), the elevated survival and fitness levels of northeastern Coyotes in anthropogenically altered northeastern North America suggest that this canid is better adapted to this region—at least in areas south of the Moose-dominated “North Woods” of northern New England. Thus, it appears that hybridization in this case positively benefited two closely related species, whereby

Eastern Wolf genes now persist in an area where the animal has been extirpated, and western Coyote genes have spread to an area where they previously did not exist (Kays et al. 2010). Finally, Coppinger et al. (2010) argued that hybridization should not be artificially prevented, as it may increase genetic variability and in some instances creates phenotypic novelties (such as the northeastern Coyote).

Nomenclature of hybrid canids in eastern North America

Hybridization of Eastern Wolves and western Coyotes (and potentially domestic dogs) over the past century has produced a highly adaptable animal with the potential for divergence along a spectrum of Coyote and wolf-like characteristics. Recent considerations of introgressive hybridization have suggested that the transfer of genetic material can be a source of genetic variation for adaptive characteristics, distinct from the parental species, thereby promoting reticulate evolution (Jiggins and Mallet 2000; Allendorf et al. 2001). Evidence of this adaptive potential is the convergence of northeastern Coyotes to more wolf-like phenotypes (Figure 3) (Way and Prioetto 2005; Way 2007a).

Renaming the northeastern Coyote to “Coywolf”

Chambers (2010, page 209) suggested that northeastern Coyotes are a part of a larger Coyote population that extends to the west and south (see Figure 1). Conversely, a similar argument could be made that northeastern Coyotes are a southern extension of hybridized Eastern Wolf populations (Wilson et al. 2009; Benson et al. 2012). I suggest that northeastern Coyotes should most appropriately be called “Coywolves,” *Canis latrans* \times *C. lycaon*, as this terminology most succinctly describes their mixed heritage and current unique genetic (Kays et al. 2010; Way et al. 2010; vonHoldt et al. 2011, page 5 and Figure S5) and morphological characteristics (this study; Way 2007a).

The term Coywolf uses the portmanteau method (i.e., a word formed by combining two other words) of naming, whereby the first word (i.e., Coyote) of the combined two is the more dominant or robust descriptor of that term. It does not suggest that this animal is equally or more wolf than Coyote. Furthermore, I believe that the vernacular terms Coyote, eastern Coyote, and northeastern Coyote (Parker 1995; Chambers 2010; vonHoldt et al. 2011) undervalue the importance of the Eastern Wolf in the ancestry of this canid, effectively ignoring the fact that (1) ~1/3 of the population's mtDNA (C1 haplotype) is derived from the Eastern Wolf (Kays et al. 2010; Rutledge et al. 2010b); (2) another >1/3 (C9 haplotype) is not found in western Coyote populations but is found in Eastern Wolves (Rutledge et al. 2010b; Way et al. 2010; Rutledge et al. 2012b, page 26); note: the C9 haplotype has also been found in low frequency in Great Lakes states (Wheeldon et al. 2010b) and mid-Atlantic region coyotes (Bozarth et al. 2011) but this may also be a product of Coyote \times Eastern Wolf hybridization); (Wheeldon

et al. 2010b, Bozarth et al. 2011); (3) microsatellite DNA indicate they are unique and separate from western Coyotes and Eastern Wolves (Way et al. 2010), despite the objections recorded in Chambers (2010); (4) they share Y-microsatellite haplotypes with Eastern Wolves (Rutledge et al. 2012b); and (5) they are morphologically unique from both of their parent species (this study). These points run counter to the claim in Chambers (2010) that they are mostly coyotes.

The recent discovery of domestic dog DNA in northeastern Coyotes (vonHoldt et al. 2011; Wheeldon and Patterson 2012) need not change this terminology, since (1) this discovery does not appear to affect the phenotype and ecology of this hybrid animal; (2) the term Coywolf most accurately describes this animal, especially since Red Wolves are described by vonHoldt et al. (2011) as only 7% less (75% vs. 82%) like the Coyote than northeastern Coyote; and (3) Chambers et al. (2012, page 32) acknowledges the introgression of domestic dog DNA into wild populations of some other *Canis*, such as Red Wolves. In addition, Anderson et al. (2009) asserted that domestic dogs are responsible for melanism in Gray Wolves in North America indicating that dogs also hybridized with wolves historically.

Future research should examine the biological species concept (Mayr 1942) in northeastern Coyotes and related *Canis*. For example, Albert et al. (2006) noted that populations that remain reproductively isolated and are almost entirely genetically distinct fulfill the criteria of distinct biological species despite the potential for gene flow with other species. Using this description, it appears that the Coywolf would qualify as a species in most of its range even though they hybridize with Eastern Wolves and western Coyotes where they are sympatric such as southeastern Canada and western New York and Pennsylvania (Figure 1).

Five types of Canis

"Here, I propose the five types of *Canis* found in North America (from smallest to largest) as (1) the western Coyote (*Canis latrans*); (2) the northeastern Coyote or Coywolf (*C. latrans* × *C. lycaon*) (east of 80° west longitude, including New England, New York, New Jersey, Pennsylvania, Ontario, and Quebec); (3) the Eastern Wolf (*C. lycaon*, including *C. rufus*); (4) the Eastern × Gray or Gray × Eastern wolf hybrids (also called the Great Lakes Wolf) (*C. lupus* × *C. lycaon* and *C. lycaon* × *C. lupus*) in the Minnesota–Ontario (western Great Lakes) area (see Koblmüller et al. 2009; Wheeldon and White 2009; Fain et al. 2010; Mech 2010); and (5) the western Gray Wolf (*C. lupus*) (Figure 1) (Table 2).

In addition to the five types of *Canis* described in Table 2, three possible additional genetic and morphological groupings could consist of the Mexican Gray Wolf (*Canis lupus baileyi*) (vonHoldt et al. 2011; Chambers et al. 2012), the mid-Atlantic Coyote (*Canis latrans*) (Bozarth et al. 2011), and the southeastern

Coyote (*Canis latrans*) (Adams et al. 2003a, b; vonHoldt et al. 2011). Wolves in Mexico are possibly the remnant of an early expansion of the Gray Wolf into North America, while research in the mid-Atlantic (Virginia) area indicates that Coyotes there are a product of hybridization between northeastern Coyotes from the north and western Coyotes from the west; hence they are an intermediate form between the northeastern Coyote and the western Coyote. vonHoldt et al. (2011) noted that mid-Atlantic and southeastern Coyote also have domestic dog genetic influence, and the southeastern Coyote may also have Red Wolf and/or Gray Wolf influence as well (Adams et al. 2003a, b).

The classification scheme (Table 2) that I propose is also supported by recent research (e.g., vonHoldt et al. 2011, page 1 and Figure 1). Despite their belief that the Eastern Wolf (which they incorrectly grouped with the Great Lakes Wolf) never existed in a pure form, vonHoldt et al. (2011) divides the four morphologically distinct wolf-like canids into the Gray Wolf, Red Wolf (i.e., Eastern Wolf), Great Lakes Wolf (i.e., Gray Wolf × Eastern Wolf hybrids), and Coyote. This study and Way (2007a) confirm that northeastern Coyotes or Coywolves are also morphologically distinct and hence warrant a fifth grouping of *Canis* in North America. Furthermore, vonHoldt et al. (2011, Figure S5) even recognized them as being a unique form of "Coyote". The continuum proposed here is applicable even with conflicting genetic interpretations (e.g., Koblmüller et al. 2009; Wilson et al. 2009; Fain et al. 2010; Mech 2010, 2011; vonHoldt et al. 2011; Chambers et al. 2012; Rutledge et al. 2012a).

Wolf recovery in the northeastern U.S.

With this "Canis soup" of different, but closely related, species (there is gene flow from *C. lycaon* to *C. lupus*) (Grewal et al. 2004; Wheeldon and White 2009; Wilson et al. 2009) and from *C. lycaon* to *C. latrans* (Wilson et al. 2009; Way et al. 2010; Rutledge et al. 2012b), distinct species status for any canid complicates conservation efforts, including *C. lupus* in eastern North America (e.g., Kolenosky 1985; Wilson et al. 2009; Fain et al. 2010; vonHoldt et al. 2011).

Wolves are listed under the Endangered Species Act in the northeastern U.S. with the goal of re-establishing viable populations of the "Eastern Timber Wolf" (stated as *Canis lupus lycaon*) (Eastern Timber Wolf Recovery Team 1992) but revised to *Canis lycaon* (Chambers et al. 2012)). From a conservation/recovery perspective, initiatives involving the re-introduction of Eastern/Red Wolves (i.e., Type 3 Wolf) or Gray Wolf × Eastern Wolf hybrids (Type 4) (Table 2) into the region will be affected by their relationship with northeastern Coyotes (Wilson et al. 2009). Any Eastern Wolves colonizing northeastern North America may already be assumed to be large "Coyotes" by state wildlife agencies because of their morphological and genetic similarities to northeastern Coyotes (Benson et al. 2012).

If the reintroduction of the Eastern Wolf into the northeast is intrinsically important because it historically existed in the northeastern U.S. and was extirpated as a result of human activities (Fain et al. 2010; Chambers et al. 2012), the feasibility of maintaining such a population sympatric with the northeastern Coyote must be addressed. The movement of Eastern Wolves into the northeastern U.S. states, such as New York and Maine, might serve only to increase introgression of *C. lycaon* into the current *C. latrans* × *C. lycaon* gene pool without achieving the re-establishment of a more wolf-like canid (i.e., Types 3–5) (Table 2), especially if all *Canis* in the region are not adequately protected (Rutledge et al. 2012b).

Alternatively, a Type 4 or Type 5 canid may be more appropriate to fill the role of an apex canid in the Moose-dominated system of northern New England and, perhaps most importantly, a Type 4 or Type 5 canid does not commonly hybridize with northeastern Coyotes (Wheeldon et al. 2010b; Benson et al. 2012; Wheel- don and Patterson 2012). Nonetheless, a recovery plan for the northeastern U.S. might allow the northeastern Coyote to evolve, given the potentially adaptive hybrid genome inhabiting these regions, as observed through the recent emergence of large wolf-like “Coyotes” in New England, and allow naturally colonizing (or rein- troduced) wolves either to hybridize with them or to form their own populations.

This would require levels of protection (e.g., such as listing *Canis* Types 2–4 or 2–5 under the Endangered Species Act due to similarity of appearances between them) (Figure 3) not currently afforded to northeastern Coyotes in the northeastern United States. Therefore, I agree with Rutledge et al. (2010a) that reducing levels of exploitation by expanding no-harvest zones and/or instituting bag limits and strict harvest regulations would be a relatively simple and inexpensive long-term way to promote the persistence of top predators, especially in a region experiencing hybridization, such as in north- eastern North America (Rutledge et al. 2012b).

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APPENDIX 1. Average body mass of western Coyotes (*Canis latrans*) (areas outside of northeastern North America), northeastern Coyotes (*Canis latrans* - C. *lycaon*), and Eastern Wolves (*C. lycaon* or *C. lupus lycaon*).

Location	Mean mass		Source	Comments
	Male	Female		
Western Coyote				
Western United States	11.4	10.5	Bekoff and Jameson (1975)	Extrapolated male and female based on 11 kg average <i>n</i> = 56 total males and females <i>n</i> = 21 males, 13 females <i>n</i> = 446 males, 383 females; maximum = 18.6 kg for males, 15 kg females <i>n</i> = 10 males, 7 females; maximum = 12.7 kg male <i>n</i> = 6 males, 7 females; maximum = 15.5 kg <i>n</i> not given <i>n</i> not given <i>n</i> = 5 males, 8 females <i>n</i> not given <i>n</i> = 46 males, 38 females <i>n</i> = 196 males <i>n</i> not given <i>n</i> = 204 total males and females <i>n</i> not given, but many captures (B. Crabtree, personal communication) <i>n</i> = 19 males, 20 females <i>n</i> = 26 males, 28 females <i>n</i> = 39 males, 30 females
Idaho	10.7	8.9	Barnum et al. (1979)	
New Mexico	11.6	9.5	Windberg et al. (1997)	
New Mexico	11.1	10.1	Young and Jackson (1951)	
Northeastern Arizona	10.5	8.8	Witham (1977)	
Tucson, Arizona	11.9	10.2	Grinder and Krausman (2001)	
North-coastal California	11.6	10.4	Neale et al. (1998)	
California	10.9	9.8	Hawthorne (1971)	
Kansas	13.3	11.6	Gipson and Kamler (2002)	
Kansas	14.1	11.8	Gier (1968)	
Texas	12.6	10.5	Young and Jackson (1951)	
Oklahoma	11.9	NA	Young and Jackson (1951)	
Iowa	13	11.4	Andrews and Boggess (1978)	
Northern Minnesota	13.2	12	Berg and Chesness (1978)	
Yellowstone National Park	13.6	11.8	Crabtree and Sheldon (1999)	
Jasper National Park, Alberta	12.1	11.5	Bowen (1982)	
Alaska	12.9	11.1	Thurber and Peterson (1991)	
Minnesota	12.8	11.4	Smith et al. (unpublished data) <i>cited by</i> Mech and Paul (2008)	
Mean	12.2	10.7		
Standard deviation	1.1	1.0		
Northeastern Coyote/Coywolf				
Cape Cod/eastern Massachusetts	18.0	16.2	this study, Way (2007a)	<i>n</i> = 18 males, 17 females; 12.3–25 kg for males, 25.1 kg for 1 female
Rhode Island	16.6	15.3	C. Brown, Rhode Island Fish and Game (personal communication)	<i>n</i> = 21 males, 15 females; maximum male = 20.9 kg, maximum female = 21.4 kg
New Hampshire	20.4	17.9	Silver and Silver (1969)	<i>n</i> = 15 males, 13 females
Vermont	17.8	16.6	Person (1988)	<i>n</i> = 10 males, 7 females; maximum = 21.4 kg
Western Massachusetts	16.9	14.5	Lorenz (1978)	<i>n</i> = 24 males, 18 females; 5 males and 1 female ≥19 kg; maximum = 25 kg male
Adirondacks, New York	14.2	11.9	Brundige (1993)	<i>n</i> = 19 total males and females
Maine	15.9	14.5	Hilton (1976)	<i>n</i> = 37 males, 22 females
Maine	15.8	13.7	Richens and Hugie (1974)	<i>n</i> = 28 males, 20 females
Maine	17.3	15.5	Harrison (1986)	<i>n</i> = 60 total males and females; maximum = 20.5 kg

APPENDIX 1. (*continued*)

Location	Mean mass		Source	Comments
	Male	Female		
Southeastern Quebec	16	14.1	Poulin et al. (1995)	<i>n</i> = 28 males, 21 females; autumn samples
Ontario	14.5	NA	Kolenosky (1971)	<i>n</i> = 19 males
Eastern New Brunswick	14.6	13.1	Dumond and Villard (2000)	<i>n</i> = 44 males, 43 females
New Brunswick/Nova Scotia	16.6	15.2	Moore and Millar (1986)	<i>n</i> = 50 males, 23 females
Nova Scotia	15.4	12.6	Sabeau (1993)	<i>n</i> = 85 males, 44 females; maximum = 21.7 kg male
Nova Scotia	16.5	13.7	Parker (1995)	<i>n</i> = 89 total males and females; maximum = 25.9 kg male
Prince Edward Island	16	15	Parker (1995)	<i>n</i> = 90 total males and females; maximum = 25 kg male
Northeastern Ontario	17.3	14.7	Wheeldon and Patterson (2012)	<i>n</i> = 44 males, 38 males; maximum = 22.8 kg male, 18.0 kg female
Mean	16.5	14.7		
Standard deviation	1.5	1.5		
Eastern Wolf				
Extreme northeastern Minnesota	30.6	26.3	Van Ballenberghe (1977); cf. Mech and Paul (2008)	<i>n</i> = 36 males, 32 females
Algonquin Provincial Park	30.3	23.9	Theberge and Theberge (2004)	<i>n</i> = 48 males, 40 females
Algonquin	30	26	Rutledge et al. (2010b)	Not included in analysis because Algonquin Provincial Park data already reported by Theberge and Theberge (2004); Benson et al. (2012) also provided similar values from the Algonquin region.
Red Wolves reintroduced into North Carolina	29.8	24.8	G. Henry (personal communication); cited in Theberge and Theberge (2004)	<i>n</i> = 21 males, 29 females
Red Wolves captured in Texas 1968–1972	23.7	21.2	Riley and McBride (1975)	Cited in Theberge and Theberge (2004)
Arkansas Red Wolves	27.6	21.6	Paradiso and Nowak (1972)	<i>n</i> = 23 males, 34 females
Algonquin 1964–1965	27.3	24.2	Pimlott et al. (1969)	<i>n</i> = 40 males, 33 females
Mean	28.2	23.7		
Standard deviation	2.6	1.9		

Spring Migratory Pathways and Migration Chronology of Canada Geese (*Branta canadensis interior*) Wintering at the Santee National Wildlife Refuge, South Carolina

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We assessed the migratory pathways, migration chronology, and breeding ground affiliation of Canada Geese (*Branta canadensis interior*) that winter in and adjacent to the Santee National Wildlife Refuge in Summerton, South Carolina, United States. Satellite transmitters were fitted to eight Canada Geese at Santee National Wildlife Refuge during the winter of 2009–2010. Canada Geese departed Santee National Wildlife Refuge between 5 and 7 March 2010. Six Canada Geese followed a route that included stopovers in northeastern North Carolina and western New York, with three of those birds completing spring migration to breeding grounds associated with the Atlantic Population (AP). The mean distance between stopover sites along this route was 417 km, the mean total migration distance was 2838 km, and the Canada Geese arrived on AP breeding grounds on the eastern shore of Hudson Bay between 20 and 24 May 2010. Two Canada Geese followed a different route from that described above, with stopovers in northeastern Ohio, prior to arriving on the breeding grounds on 9 June 2010. Mean distance between stopover sites was 402 and 365 km for these two birds, and total migration distance was 4020 and 3650 km. These data represent the first efforts to track migratory Canada geese from the southernmost extent of their current wintering range in the Atlantic Flyway. We did not track any Canada Geese to breeding grounds associated with the Southern James Bay Population. Caution should be used in the interpretation of this finding, however, because of the small sample size. We demonstrated that migratory Canada Geese wintering in South Carolina use at least two migratory pathways and that an affiliation with the Atlantic Population breeding ground exists.

Key Words: migration, Canada Geese, *Branta canadensis interior*; satellite telemetry, Atlantic Population, Southern James Bay Population, staging areas, stopover sites, Atlantic Flyway, wintering ecology, South Carolina, Quebec, Ontario.

In North America, Canada Goose (*Branta canadensis*) populations are defined and partially managed based on affiliations with breeding grounds. Three populations of migratory Canada Geese occur in the Atlantic Flyway: the Atlantic Population, the North Atlantic Population, and the Southern James Bay Population (Hindman et al. 2004). Canada Geese from the Atlantic Population (predominantly *Branta canadensis interior*) nest north of 48° north latitude in Quebec along the northeastern shore of Hudson Bay and the interior of the Ungava Peninsula (Davies and Hindman 2008*). These Canada Geese winter from southern Ontario eastward through the southernmost part of Quebec and southward to South Carolina, with concentrations on the Delmarva Peninsula and in portions of New York, southeastern Pennsylvania, New Jersey, and Virginia (Davies and Hindman 2008*).

Canada Geese from the North Atlantic Population (predominantly *B. c. canadensis*) breed in Labrador, the interior of Newfoundland, and eastern Quebec, and they winter along the Atlantic coastal zone from Labrador to South Carolina (Hindman et al. 2004). Canada Geese from the Southern James Bay Population (predominantly *B. c. interior*) breed along the southwestern shore of James Bay in Ontario and on Akimiski Island in Nunavut (Hindman et al. 2004; Abraham et al. 2008*). These Canada Geese winter in both the Atlantic and Mississippi flyways and are managed jointly by each flyway council (Hindman et al. 2004). In the Atlantic Flyway, these Canada Geese migrate through western Pennsylvania and winter in the Piedmont regions of North and South Carolina (Hindman et al. 2004). Both the breeding and the non-breeding ranges and habitats are typically well defined and documented for each population.

Over the past several decades, the wintering distribution of Canada Geese throughout eastern North America has shifted northward. Factors such as climate change, climate severity during winter, changes in farming and land-use practices, interactions with temperate-nesting Canada Geese (*B. c. maxima*, Giant Canada Geese), and the differential survival of southern-wintering cohorts are suspected to have contributed to the northern shift in winter distribution (Abraham et al. 2008*; Davies and Hindman 2008*).

In the Atlantic Flyway, this northern shift of migratory Canada Geese is evident in many southeastern states, where the abundance of wintering birds appears to be decreasing. Although numbers of migrant Canada Geese are low on southern wintering grounds, those Canada Geese that do return to wintering grounds in southern states appear to exhibit strong site fidelity to public lands, notably national wildlife refuges (Bellrose 1980; Orr et al. 1998; Combs et al. 2001).

Such is the case in South Carolina, where the number of migrant Canada Geese has been dwindling since the 1960s. Those birds that do return have an affinity for public lands, such as the Santee National Wildlife Refuge. Counts of migrant Canada Geese at the Santee National Wildlife Refuge peaked in the 1960s at approximately 40 000 birds; currently, only 500 to 1 000 Canada Geese appear to winter in and adjacent to the refuge (U.S. Fish and Wildlife Service 2008).

Canada Geese from the North Atlantic Population and the Southern James Bay Population have historically been associated with national wildlife refuges in South Carolina (Hindman et al. 2004; Davies and Hindman 2008*). Additionally, re-sighting of neck-collared Canada Geese during winter in the 1980s demonstrated an affiliation between Canada Geese from both the Atlantic Population and the Southern James Bay Population and wintering grounds in South Carolina (Malecki and Trost 1986). Despite recent changes in the distribution and abundance of Canada Geese in the Atlantic flyway, examinations of breeding and wintering ground affiliations for birds wintering in the southernmost extent of the range have been assessed only through banding data. Therefore, our objectives were to use satellite transmitters to determine migratory pathways, migratory chronology, and breeding ground affiliation of Canada Geese that winter at the southernmost extent of the migratory range, in Santee National Wildlife Refuge, South Carolina.

Methods

Canada Geese were captured on the Santee National Wildlife Refuge (Figure 1) located along Lake Marion, a reservoir of 44 758 ha created by the South Carolina Public Service Authority between 1939 and 1942. The Santee National Wildlife Refuge is the most significant inland area for migratory waterfowl in South Carolina (U.S. Fish and Wildlife Service 2008), and it is managed in part to support Canada Geese from the Southern James Bay Population in the southeastern

Atlantic states. Migrant Canada Geese winter at the Santee National Wildlife Refuge from late November until early March.

Canada Geese ($n = 22$ females and 6 males) were captured on the Bluff Unit of the Santee National Wildlife Refuge during December of 2009 using rocket nets stationed in agricultural fields. Because the Santee National Wildlife Refuge was primarily interested in determining wintering habitat use by migrant Canada Geese in and adjacent to the Refuge, all satellite fitting needed to be completed as early in the winter season as possible (i.e., preferably prior to the end of December). Measurements of body mass (to the nearest 100 g), culmen length (to the nearest 0.01 mm), tarsus length (to the nearest 0.01 mm), and wing chord (to the nearest 5 mm) were recorded for all captured Canada Geese. We used broad ranges of body mass to distinguish subspecies following the ranges in body mass provided in Bellrose (1980).

After-hatch-year males and females deemed to be migratory *B. c. interior* (from either the Southern James Bay Population or the Atlantic Population) or *B. c. canadensis* (from the North Atlantic Population) were fitted with satellite (PTT) transmitters (either 45 gram, Microwave Telemetry Inc., Columbia, Maryland, U.S., or 60 gram TAV-2456 Telonics Inc., Mesa, Arizona). Transmitters were attached dorsally between the wings using a harness made of Teflon ribbon (Bally Ribbon Mills, Bally, Pennsylvania.). Transmitters were programmed on a three-day duty cycle through 30 April 2010 and a 10-day duty cycle thereafter. Canada Geese with transmitters were fitted with a federal U.S. Geological Survey aluminum leg band and a green leg band with a white alphanumeric code. All trapping and handling procedures were approved by the Clemson University Institutional Animal Care and Use Committee and the U.S. Geological Survey.

Satellite locations were obtained using the Argos data collection system (Argos 2008*). We choose one location per bird per day to use in subsequent analyses, based on criteria outlined in Miller et al. (2005) and Haukos et al. (2006). Location classes 3 (estimated error of <150 m), 2 (estimated error of 150 to 350 m), and 1 (estimated error of 350 to 1000 m) were favored. We used Hawth's Tools (Beyer 2004*) for ArcGIS 9.3 to determine migratory pathways and to calculate the total migration distance, as well as distances between stopover sites from the date of departure from the Santee National Wildlife Refuge until birds arrived on the breeding grounds.

North American land cover data (Commission for Environmental Cooperation 2010) were used to identify the primary land cover types in the landscapes surrounding each stopover or staging area used during spring migration. A 10-km buffer was placed around each stopover or staging area, and the percentage of each land cover type within the buffered area was determined. We chose a 10-km buffer because the range of all relocations at individual stopover sites was usually

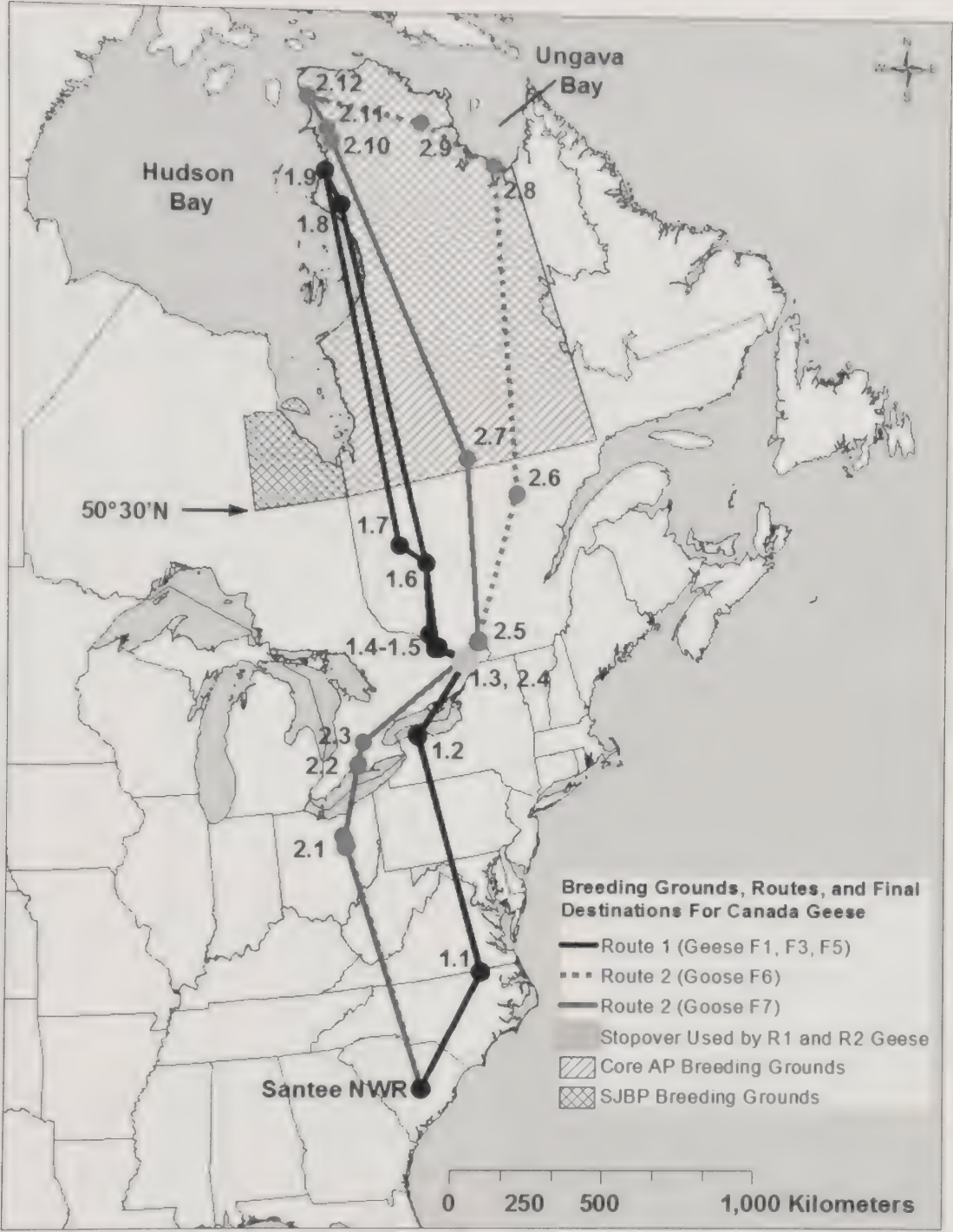


FIGURE 1. Migratory pathways used by Canada Geese (*Branta canadensis interior*) fitted with satellite transmitters during spring migration from wintering grounds at the Santee National Wildlife Refuge in South Carolina, 5 March 2010, to arrival on breeding grounds. Abbreviations (e.g., F1) refer to bird IDs listed in Table 1. Numbered locations (e.g., 1.1, 1.2) represent sequential stopover sites on Route 1 or Route 2 (defined in Table 2). Satellite tags were programmed on a three-day duty cycle through 30 April and a 10-day duty cycle thereafter; lines are therefore interpretations to link points and do not reflect known flight paths. Note that Route 2 (Female 6) and Route 2 (Female 7) overlap from Santee National Wildlife Refuge through points 2.1 to 2.4. AP refers to Atlantic Population and SJBP refers to Southern James Bay Population.

contained within this radius and because previous studies of wintering and migrating Canada Geese found that most daily movements during the stopover period were within a 10-km radius (Reed et al. 1977).

Results

We trapped for a total of 143 hours over 24 days during December 2009 on the Bluff Unit of the Santee National Wildlife Refuge. Canada Geese were captured on just 2 of the 24 trapping days, thus limiting our choice in selecting individuals for satellite tracking (i.e., we were not able to restrict tagging to one bird per capture event, as planned). Six Canada Geese were captured together on 15 December 2009 and each was fitted with a satellite transmitter. Two of these birds, Male 1 and Female 2, were already banded at the time of capture. The band return information we later received indicated the banding site was within the breeding range of the Atlantic Population. Five Canada Geese were captured on 18 December 2009 and two were fitted with satellite transmitters (Table 1).

The Canada Geese fitted with satellite transmitters departed Santee National Wildlife Refuge between 5 and 7 March 2010. We selected 164 locations, post-filtering, between the date of departure and either the date of last transmission or the date of arrival on the breeding grounds (Table 1). Of the eight transmitters deployed, three ceased transmission during spring migration before the birds arrived at the breeding grounds. The cause of transmitter failure remains undetermined. The remaining five Canada Geese completed the spring migration to breeding grounds associated with the Atlantic Population on the Ungava Peninsula in Quebec.

Six Canada Geese followed a route with stopovers in northeastern North Carolina (stopover 1.1) and western New York (stopover 1.2) (hereafter Route 1) (Table 2 and Figure 1). Three of these transmitters (on Male 1 and Females 2 and 4) failed in late April. The last known locations were in southeastern Ontario. Females 1, 3, and 5 completed the spring migration to the eastern shores of Hudson Bay within the breeding grounds of the Atlantic Population (Figure 1). Along Route 1, the longest stopovers occurred in southeastern Ontario and southern Quebec (stopovers 1.4 and 1.5) (Table 2), with Canada Geese remaining in these areas from ca. 19 March to 1 April 2010 and from 3 April to 2 May 2010. Mean distance between stopovers for Females 1, 3, and 5 was 417 km (SE 76), and mean total migratory distance was 2838 km (SE 346) (Table 3). Canada Geese arrived on the breeding grounds ca. 24 May 2010.

Females 6 and 7 followed a route with stopovers in northeastern Ohio (stopover 2.1), southwestern Ontario (stopovers 2.2 and 2.3), southeastern Ontario (stopover 2.4), and southern Quebec (stopover 2.5) prior to arrival on the breeding grounds of the Atlantic Population (hereafter Route 2) (Table 2 and Figure 1). The longest stopovers along Route 2 also occurred in southeastern

TABLE 1. Capture date, date of last transmission, and migratory relocation data for migrant Canada Geese (*Branta canadensis interior*) captured at the Santee National Wildlife Refuge, Summerton, South Carolina, in December 2009 and fitted with satellite transmitters.

ID	Capture date	Date of last relocation on wintering grounds	Total number of relocations ^a	Complete migration to breeding grounds?	Date of last transmission	Location of last transmission
Male 1	15 December 2009	5 March 2010	16	No	25 April 2010	Southeastern Ontario/southern Quebec along the Ottawa River
Female 1	15 December 2009	5 March 2010	24	Yes	20 November 2010	Fall migration; Haliburton County, Ontario
Female 2	15 December 2009	5 March 2010	19	No	30 April 2010	Southeastern Ontario/southern Quebec along the Ottawa River
Female 3	15 December 2009	5 March 2010	21	Yes	20 May 2010	Atlantic Population breeding grounds
Female 4	15 December 2009	5 March 2010	16	No	22 April 2010	Southeastern Ontario/southern Quebec along the Ottawa River
Female 5	15 December 2009	5 March 2010	22	Yes	9 June 2010	Atlantic Population breeding grounds
Female 6	18 December 2009	5 March 2010	23	Yes	24 February 2011	Fall migration/wintering; Talbot County, Maryland
Female 7	18 December 2009	5 March 2010	23	Yes	28 August 2010	Atlantic Population breeding grounds

^a Number of relocations after filtering ARGOS data to include only one relocation per day from location classes 1–3.

TABLE 2. Migration routes and duration of stay at stopover and staging sites used by migrant Canada Geese (*Branta canadensis interior*) captured at the Santee National Wildlife Refuge, Summerton, South Carolina, in December 2009.

Migration route	Stopover number	Stopover description	Range of PTT transmission days at stopover ^c
Route 1 ^a	1.1	Northeastern North Carolina	8–9 March 2010
	1.2	Western New York	11–17 March 2010
	1.3	Southeastern Ontario	19 March–1 April 2010
	1.4	Southeastern Ontario; southern Quebec	3 April–2 May 2010
	1.5, 1.6, 1.7, 1.8	Female 1: southwestern Quebec (south of 50°30' north latitude)	
		Female 3 and Female 5: southern Quebec, then on to the breeding grounds of the Atlantic Population (north of 50°30' north latitude on 20 May)	
		Female 1: breeding grounds of the Atlantic Population, Hudson Bay coast	
	1.8, 1.9	Female 5: moves slightly north on the breeding grounds of the Atlantic Population	5–20 May 2010
		Northeastern Ohio	Arrival ca. 24 May 2010
	2.1	Southwestern Ontario	8–14 March 2010
Route 2 ^b	2.2	Southwestern Ontario	17 March–4 April 2010
	2.3	Southwestern Ontario	7 Apr 2010
	2.4, 2.5	Southeastern Ontario	10–30 April 2010
	2.6, 2.7	Female 6: southern Quebec (south of 50°30' north latitude); Female 7: Quebec (north of 50°30' north latitude)	
		Female 6: coast of Ungava Bay; Female 7: coast of Hudson Bay	10 May 2010
	2.8, 2.9, 2.10, 2.11	Breeding grounds of the Atlantic Population, coast of Hudson Bay	20–30 May 2010
	2.12		Arrival ca. 9 June 2010

^a Route taken by birds Females 1, 3, and 5. Male 1, and Females 2 and 4 also followed this route until late April when the transmitters failed.

^b Route taken by Females 6 and 7.

^c Represents range of dates during which all birds traveling the route were present in the area. Dates may not be the same for each goose due to particular duty cycle of the transmitter, but were usually only one day apart.

TABLE 3. Spring northward migration routes, number of stopover sites, and distance traveled by migrant Canada Geese (*Branta canadensis interior*) captured at the Santee National Wildlife Refuge, Summerton, South Carolina, in December 2009 and fitted with satellite transmitters.

	ID	Migration route	Number of stopovers	Breeding ground	Mean distance between stopovers (km) ± SE	Total migration distance (km)
Canada Geese that completed spring migration	Female 1	Route 1	7	Atlantic Population	286.9	2150.9
	Female 3	Route 1	5	Atlantic Population	519.2	3115.4
	Female 5	Route 1	6	Atlantic Population	463.9	3247.3
	Mean ± SE				417.3 ± 76.0	2837.9 ± 345.6
	Female 6	Route 2	8	Atlantic Population	402.0	4020.4
Canada Geese with transmitters that failed during migration	Female 7	Route 2	8	Atlantic Population	365.1	3650.5
	Mean ± SE				383.5 ± 18.5	3835.5 ± 185.0
	Male 1	Route 1	4	N/A	407.0	1628.1
	Female 2	Route 1	4	N/A	407.2	1628.9
	Female 4	Route 1	4	N/A	407.3	1629.5

Ontario (Table 2), with Canada Geese remaining in these areas from ca. 17 March to 4 April 2010 and from 10 to 30 April 2010. Canada Geese following this route also staged in the Ottawa River valley area of south-eastern Ontario and southwestern Quebec before continuing north.

Females 6 and 7 completed the spring migration to the eastern shores of Hudson Bay around 9 June 2010. However, Female 6 took a lengthier migratory path, with a mean distance between stopover sites of 402 km and a total migration distance of 4020 km, and Female 7 had a mean distance between stopover sites of 365 km and a total migration distance of 3650 km (Table 3). Female 7 made a direct flight from southern Quebec to the breeding grounds of the Atlantic Population on Hudson Bay, while Female 6 first flew to the south shore of Ungava Bay, then along the coast of Ungava Bay and across the Ungava Peninsula before settling on the east side of Hudson Bay.

Cropland was the most common habitat type within 10-km buffers at stopover and staging sites utilized by Canada Geese (Table 4). Cropland comprised 35% to 74% of the habitat at stopover sites in the United States and southern Canada. This habitat type decreased as a landscape component once Canada Geese migrated north of staging areas in the Ottawa River valley.

Discussion

Five of the eight Canada Geese fitted with satellite transmitters at Santee National Wildlife Refuge during the winter of 2009–2010 completed the spring migration to the breeding grounds of the Atlantic Population. Birds that were captured together did not all follow the same migration route to the breeding grounds. Females 1, 3, and 5 shared a common path (Route 1) that is typically associated with the breeding grounds of the Atlantic Population. However, Female 1 diverged from Females 3 and 5 north of southern Quebec. Females 6 and 7 shared a common path (Route 2) but diverged as they traveled through Quebec (Figure 1). Unlike Route 1, the portion of Route 2 that is within the USA is typically associated with birds destined for the breeding grounds of the Southern James Bay Population. The mechanisms underlying route choice in our study are unclear, but may be related to mate choice, short-term weather patterns, or site fidelity.

The remaining three transmitters we deployed failed during migration. Banding returns demonstrated that two of these birds had been banded on the breeding grounds of the Atlantic Population in 2001 (Male 1) and 2003 (Female 2). Whether Male 1 and Female 2 were breeders from the Atlantic Population or resident Canada Geese from the Ottawa River valley that visited the breeding grounds of the Atlantic Population as moult-migrants and then wintered at Santee National Wildlife Refuge is not clear. None of the Canada Geese from our study were affiliated with the breeding grounds of the Southern James Bay Population.

TABLE 4. Proportion of habitat classified as cropland within 10-km buffers of all stopover and staging sites used by spring migrant Canada Geese (*Branta canadensis interior*) captured at the Santee National Wildlife Refuge, South Carolina, in December 2009.

Stopover site	% Cropland	Most common non-cropland land cover (%)
South Carolina	34.8%	Water (22.8%)
Northeastern North Carolina	54.2%	Broadleaf deciduous forest (27.3%)
Ohio	74.4%	Temperate or subpolar broadleaf deciduous forest (21.3%)
Western New York	42.8%	Water (31.7%)
Southwestern Ontario	70.0%	Broadleaf deciduous forest (10.3%)
Southeastern Ontario/southern Quebec (along the Ottawa River)	36.3%	Temperate or subpolar broadleaf deciduous forest (33.2%)
Quebec south of 50°30' north latitude	9.0%	Temperate or subpolar broadleaf deciduous forest (32.4%)
Ungava Bay	0.0%	Subpolar or polar barren lichen/moss (39.0%)
Hudson Bay	0.0%	Subpolar or polar grassland lichen/moss (76.8%)

Canada Geese neck-collared on the breeding grounds of the Southern James Bay Population have previously been re-sighted wintering at Santee National Wildlife Refuge. For example, several Canada Geese (<5) marked with neck collars on the breeding grounds of the Southern James Bay Population were observed among the approximately 500 migratory Canada Geese that wintered at Santee National Wildlife Refuge during the winter of 2008–2009 (M.G. personal observation).

After leaving the Santee National Wildlife Refuge, the Canada Geese fitted with satellite transmitters first traveled to either northeastern North Carolina or northeastern Ohio. Canada Geese captured on wintering grounds in the North Carolina coastal plain and in South Carolina at both the Santee National Wildlife Refuge and the Carolina Sandhills National Wildlife Refuge have used these same stopover areas (Malecki and Trost 1986; Fuller 2000*). Movements through the United States occurred relatively quickly, with Canada Geese remaining at stopovers for only 1–7 days. However, once the Canada Geese reached the Great Lakes and the Ottawa River valley areas of Canada, migratory movements slowed. Canada Geese that were neck-collared between 1983 and 1985 at the Pee Dee National Wildlife Refuge in North Carolina, at the Carolina Sandhills National Wildlife Refuge in South Carolina, and at the Santee National Wildlife Refuge also showed an affinity for southeastern Ontario during spring migration (Malecki and Trost 1986). Following lengthy staging events at stopovers 1.3, 1.4, 1.5, 2.4, and 2.5, Canada Geese fitted with satellite transmitters generally relocated north, making a few shorter flights in Quebec south of the breeding grounds of the Atlantic Population (stopovers 1.6, 1.7, 2.6, and 2.7). Although there were two separate migratory routes, the one similarity between Route 1 and Route 2 is the use of the stopover in southeastern Ontario and southern Quebec near the Ottawa River.

Satellite telemetry data reveal that the Canada Geese from our study shared migratory pathways with Canada Geese banded in the southeastern states and with Canada Geese marked with satellite transmitters on

the breeding grounds of the Atlantic Population. In addition, we found similarities in migration chronology between our Canada Geese and those marked with satellite transmitters on the coast of Hudson Bay and Ungava Bay during the summers of 1996 and 1997 (Malecki et al. 2001). Although the birds tracked in 1996 and 1997 had a more widely distributed range of terminal wintering locations (including New Jersey, Maryland, Delaware, Virginia, Massachusetts, and Connecticut), the date of departure from the wintering grounds and dates of arrival at various stopovers in the United States and Canada were similar to those in this study (Malecki et al. 2001). For example, in spring of 1997, Canada Geese departed wintering locations by early March, then remained south of 47° north latitude (the degree of latitude separating resident from migrant geese) during the month of April. Canada Geese then moved north of 47° north latitude during May, arriving on breeding grounds between 25 May and 2 June 1997 (Malecki et al. 2001). This chronology nearly matches that of the Canada Geese satellite-tagged in our study: they departed Santee National Wildlife Refuge by 5–7 March, remained south of 50°30' north latitude until early May, and reached the breeding grounds of the Atlantic Population between 24 May and 9 June 2010.

In our study, agricultural fields were the dominant habitat type at stopover and staging sites in both the United States and southern Canada. Studies on habitat use and diet (Reed et al. 1977; Giroux and Bergeron 1996) have also shown that migratory Canada Geese and Greater Snow Geese (*Chen caerulescens atlantica*) in southern Canada frequent lands characterized by agricultural activities, and there appear to be few public lands in the area managed for waterfowl (J. Hughes, personal communication, 2010). The primary forage crop in southeastern Ontario and southwestern Quebec is corn, but soybean, wheat, oats, and barley are also available, as are dairy farms, which also provide foraging areas (Javorek et al. 2007). Canada Geese and Greater Snow Geese staging along the St. Lawrence River, which provides habitats similar to those utilized by the Canada Geese equipped with transmitters in our

study, feed in cornfields, hayfields, and marshes, and they roost in flooded fields, rivers, and marshes (Bechet et al. 2003, 2004).

Birds likely remained on these cropland staging grounds obtaining nutrients used for breeding until weather conditions in the north permitted departure (Reed et al. 1977). The habitat at stopovers 1.7 and 2.6 are among the northernmost agricultural sites in Quebec. At stopovers 1.6 to 1.9 and 2.6 to 2.12, land cover is mostly dominated by forested habitats, with smaller percentages of grassland and wetland and a small amount of agricultural land. Therefore, the agricultural areas utilized during the lengthy staging period in southeastern Ontario and southern Quebec may provide critical staging areas for migratory geese from South Carolina and other southern states to gain body mass and nutrient reserves before departing for the breeding grounds (Alisauskas et al. 1988; Drent et al. 2007).

Canada Geese from both the Atlantic Population and the Southern James Bay Population are experiencing changes in their non-breeding habitats. For example, staging and wintering areas used by Canada Geese from the Atlantic Population support increasing numbers of Greater Snow Geese and resident Canada Geese, which may forage on agricultural food resources previously dominated by migratory Canada Geese (Davies and Hindman 2008*). Furthermore, the regions in which wintering and staging areas are found are also experiencing habitat loss and habitat conversion pressure from development (Brown et al. 2005).

Survey data demonstrate that the number of migratory Canada Geese wintering in the U.S. southeast has been declining for at least two decades, with causes attributed primarily to changes in farming and land use practices on staging and wintering grounds as well as to the lower survival of southern cohort Canada Geese and increasing populations of temperate-nesting Canada Geese (Abraham et al. 2008*; Davies and Hindman 2008*). Furthermore, in the Atlantic Flyway, Canada Geese from the Atlantic Population do not appear to be as strongly associated with public lands during the winter (Addy and Heyland 1968; Harvey 1987; Harvey et al. 1998). Providing habitat at key stopover, staging, and wintering locations will therefore require targeted conservation actions on both public and private lands. Federally funded and state-funded conservation programs (e.g., U.S. Farm Bill Programs) that provide financial incentives, privately funded conservation actions, and grant programs (e.g., U.S. North American Wetland Conservation Act) are tools that could be used to ensure that suitable stopover, staging, and overwintering habitat for migratory Canada Geese exist.

Despite what appears to be a strong reliance by Canada Geese on private lands as stopover habitat during our study, wintering and staging habitat for migratory geese are provided by state and federal public

lands. Should private lands such as agricultural fields be developed, as is occurring adjacent to the Santee National Wildlife Refuge in South Carolina, geese that use those habitats may need to relocate. Identifying sites where habitat conversion or loss is likely to occur on or adjacent to private lands that currently serve as stopover, staging, or wintering areas throughout the Atlantic Flyway could help prioritize future conservation actions for migratory geese.

Our satellite telemetry data and the banding returns from two of the Canada Geese fitted with satellite transmitters demonstrated that geese from the breeding grounds of the Atlantic Population wintered at the Santee National Wildlife Refuge, which currently appears to represent the southernmost extent of the wintering range for this breeding population. Observational data from the Santee National Wildlife Refuge also demonstrated that Canada Geese from the Southern James Bay Population winter on the refuge. Our limited data do not allow the proportion of the southernmost wintering birds from each breeding population at the Santee National Wildlife Refuge to be estimated, and a study designed to further investigate breeding ground affiliations is warranted. Our results demonstrate that migratory Canada Geese wintering in southern states are associated with multiple breeding grounds and rely strongly on private agricultural lands for migratory habitat.

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Visitations by Snowshoe Hares (*Lepus americanus*) to and Possible Geophagy of Materials from an Iron-Rich Excavation in North-Central British Columbia

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Fecal pellet samples and photo data were collected and analyzed to investigate the suspected occurrence of geophagy of soils by Snowshoe Hares (*Lepus americanus*) at a small iron-rich mineral excavation in north-central British Columbia. Pellet samples from Snowshoe Hares collected near the excavation site in both February 2004 and 2005 showed higher levels of iron (II) sulphate in pellets than in samples from control areas ($P < 0.05$). Using remote wildlife camera technology, we determined that Snowshoe Hares accounted for 72% of visits by mammals to the site. Ninety percent of these visits occurred at night; this timing corresponds with the use of mineral licks by several other species of mammals in North America. Use occurred in winter (49%) and spring (47%), but was rare in summer and autumn, and may have coincided with periods of nutritional stress in Snowshoe Hares.

Key Words: excavation, fecal pellet, geophagy, iron, Snowshoe Hare, *Lepus americanus*, soil, wildlife camera, John Prince Research Forest, British Columbia.

The deliberate consumption of soil by animals (geophagy) has been documented in many species, including humans and other primates, ungulates, and birds (Krishnamani and Mahaney 2000; Mahaney et al. 2000). Several hypotheses have been put forward to provide explanations for this behaviour, all relating to either gastrointestinal disorders or mineral deficiencies (Krishnamani and Mahaney 2000). Consumption of certain clay-rich soils allows relief from diarrhea and acts as a buffer against elevated levels of stomach acids (Dominy et al. 2004). Soil consumption also frequently occurs in order to neutralize plant secondary compounds, such as tannins (Faber et al. 1993; Houston et al. 2001). The minerals most commonly found in consumed soils include sodium, calcium, magnesium, potassium, iron, and aluminum (Wilson 2003).

There is little information in the literature pertaining to the nutritional requirements of hares (*Lepus* spp.); although geophagy has been documented in this genus, it is usually in relation to dietary sodium needs. Faber et al. (1993) reported on the utilization of salt blocks by Mountain Hares (*Lepus timidus*) in Sweden and suggested that increased use corresponded to increased nutritional stress associated with reproduction and seasonal dietary excesses of potassium. Incidents of soil consumption for the purposes of obtaining iron are uncertain; although Arthur and Gates (1988) reported that Black-tailed Jackrabbits (*Lepus californicus*) obtained dietary iron from soil, the study did not conclude that this was the likely purpose of soil consumption. Krishnamani and Mahaney (2000) noted, however, that most soils eaten by primates are reddish in colour and contain iron oxide.

The dietary iron requirements for rabbits and hares (Leporidae) are largely unknown. Iron is nonetheless an important mineral and plays several physiological roles in mammals, including oxygen transport. New Zealand White (domestic *Oryctolagus cuniculus*) does given supplemental iron sulphate responded to treatments with increases in maternal weight and litter size at birth and weaning; reduced mortality at birth and weaning; and increases in kit weight at weaning, milk yield, and levels of maternal plasma progesterone and estradiol-17 β (El-Masry and Nasr 1996). These findings suggest an overall increase in reproductive performance with iron supplementation.

The purpose of this study was to investigate, through the analysis of soils, fecal pellet samples, and wildlife camera data, the suspected occurrence of geophagy by Snowshoe Hares (*Lepus americanus*) at an iron-rich mineral excavation in north-central British Columbia that we discovered in the spring of 2001.

Methods

Site characteristics

The site is located on the northwest-facing bank of a mineral lick in the John Prince Research Forest (54°35'N, 124°35'W), 50 km northwest of Fort St. James, British Columbia. The cavity appears to be natural, having been partially excavated by animals through to mineral soils, but not into parent materials. The excavation was not made by people. The site is located in a spruce–pine (*Picea–Pinus*) stand ~120 years old in the Dry Warm Sub-Boreal Spruce biogeoclimatic subzone (SBSdw) (Meidinger et al. 1991) at an altitude of 791 m above sea level. Soils in the area

are composed primarily of orthic gray luvisols, which are neutral to slightly alkaline. The excavation was located beneath the root structure of a 35-year-old hybrid White Spruce (*Picea glauca* × *engelmannii*) tree, and the dimensions of the cavity, as measured in the spring of 2003, were 22 cm deep by 30 cm wide by 16 cm high.

Using microscopy, we sorted soils and measured particle sizes to the nearest micrometer on a homogenized subsample of 13.98 g of a handful of the material we collected in the spring of 2003. We also used microscopic hair analysis of samples of hairs that we collected from the rim of the excavation opening in an attempt to determine species moving in and out of the excavation.

Data collection and analysis

Photo data were collected from the late summer of 2003 through February 2005 using a TrailMaster TM1550 infrared trail monitor. The camera was mounted in a tree approximately 5 m from the mouth of the excavation and 1.5 m above the ground. Because the date and time imprinter on the camera was not functioning, photos were classified as either night or day based on the light conditions in the background of the photo. Season was assessed using date of film collection and the progression of plant phenology in the photos: mid-November through early March was classified as winter; mid-March to the end of May was classified as spring; and June through mid-November was classified as summer and autumn combined due to the small number of photographs taken during that period.

Fecal pellets were collected in February of 2004 and 2005 from three different sampling areas: those collected within a 20-m radius of the excavation were classified as "excavation" site; pellets collected from 1–2 km from the excavation were classified as "control near," and samples collected farther than 2 km away (range 2–156 km) were classified as "control far."

Pellets were dried for 7 days at 20°C under a fume hood to a constant weight, then ground with a mortar and pestle, and analyzed for mineral content along with samples from the soil itself using an inductively coupled plasma (ICP) analyser.

Because there was extensive evidence of Snowshoe Hare browse on current annual shoots of Prickly Rose (*Rosa acicularis*) in the study area, we collected current annual shoots of this plant (~20 individual plant specimens) in February of 2004 and dried and ground them for ICP analysis. Samples were taken only from the control near sites because there was no evidence of browsing on any plant species at the excavation site itself.

Iron (II) sulphate concentration differences in feces were compared among sample areas using a two-factor analysis of variance with year and distance category as main and interaction effects. A Tukey's honestly significant difference (HSD) test was used for post-hoc comparisons (Gotelli and Ellison 2004). We specified

an alpha level of $P < 0.05$. All analyses were conducted using Statistica 9.0 (Statsoft 2009).

Results

Using Adorjan and Kolenosky (1969), we identified hair samples collected from the opening of the excavation as those of Snowshoe Hare. We classified all aggregate materials from the excavation as subangular blocky (Expert Committee on Soil Survey 1983) and determined that the soil was composed of several elements, but contained 86% iron. Soil particle sizes ranged from a fine powder to up to 2.5 cm in diameter with a mean particle size of 1.227 mm (SD 4.206).

Of 348 photographs recorded between late summer 2003 and February 2005, 130 contained images of animals. Of these, Snowshoe Hares were the most often photographed (Figure 1, Table 1). Table 1 details the occurrence of mammals at the site of the excavation. Two Canada Lynx (*Lynx canadensis*) were observed in the winter of 2003, and a pair of Snowshoe Hares was observed in April of 2004.



FIGURE 1. Snowshoe Hare (*Lepus americanus*) (circled) photographed at a mineral lick in the John Prince Research Forest, northwest of Fort St. James, British Columbia. The camera was set to take photographs of animals entering and exiting the iron-rich mineral excavation (arrow) over a 1.5-year period (Winter 2004).

Analysis of fecal samples indicated levels of iron (II) sulphate were higher in samples from the excavation site than from the controls in both 2004 and 2005 ($F_{1,2} = 7.795$; $P = 0.003$; Figure 2). There were no differences between years ($F_{1,2} = 1.617$; $P = 0.216$) and there was no interaction between area and year ($F_{1,2} = 0.932$; $P = 0.408$). Tukey's post-hoc comparisons indicated that differences existed specifically between Control Far 2004 samples and Excavation 2005 samples ($P = 0.012$) and between Control Far 2005 and Excavation 2005 samples ($P = 0.013$). The levels of iron in Prickly Rose samples were not higher than the levels of iron that we found in feces, and levels in Prickly Rose were similar in all collection locations.

TABLE 1. Number of photographs recorded (*n*) by species and season; time of day is the percentage of total pictures of that species in the particular season. Number is beam breaks resulting in photographs, and does not necessarily represent independent occurrences. Photographs taken in summer and autumn are combined due to small numbers recorded. In some instances, photographs were triggered by weather events and therefore did not contain photographs of animals.

Species	Photos (<i>n</i> = 130)	Winter		Spring		Summer and Autumn		Annual total
		Day (%)	Night (%)	Day (%)	Night (%)	Day (%)	Night (%)	
Snowshoe Hare (<i>Lepus americanus</i>)	94	4.5	44.5	4	43	2	2	100
Red Squirrel (<i>Tamiasciurus hudsonicus</i>)	17	23.5	—	76.5	—	—	—	100
Moose (<i>Alces alces</i>)	10	—	70	—	30	—	—	100
Deer (<i>Odocoileus</i> spp.)	7	—	—	85.7	14.3	—	—	100
Canada Lynx (<i>Lynx canadensis</i>)	2	—	100	—	—	—	—	100

Discussion

Camera trap data from our study site indicate that Snowshoe Hares were the most common species using the excavation and that their activity was predominantly nocturnal, with 90% of visits occurring at night. Mineral consumption by other animals at mineral licks also tends to be a night-time activity (Fraser and Reardon 1980; Tankersley and Gasaway 1983; Couturier and Barrette 1988; Voigt et al. 2007). We found no evidence that this area was being used as a daybed or nursery or for cover by Snowshoe Hares or other animals. Rather, materials in the excavation appeared to be continually disturbed rather than matted or compacted with use.

Peak activity was recorded during winter and spring. This time frame corresponds to periods when Snowshoe Hares have reduced access to high-quality forage and may be under increased nutritional stress (Hodges et al. 2006). Murray et al. (1998) speculated that in years of peak Snowshoe Hare population numbers, nutritional stress can be exacerbated by increased intestinal parasite loads. Because iron supplementation can significantly reduce parasite loads (Olsen et al. 2000), increased iron consumption through geophagy may help to improve body condition during periods of nutritional and reproductive stress that coincide with winter and spring.

The photograph of a pair of Snowshoe Hares at the excavation site in spring 2004 suggests that the time period of use may correspond to reproductive events. The breeding season for Snowshoe Hares may extend up to seven months (March–September) across their geographical range and is strongly associated with photoperiod (Murray 2003). The onset of ovulation in Snowshoe Hares appears to be affected by environmental and ecological factors. For example, Vaughn and Keith (1981) demonstrated that overwinter body mass loss in female Snowshoe Hares is correlated with delays in the onset of conception in spring. This implies that the nutritional fitness of females affects breeding readiness (Murray 2003). El-Masry and Nasr (1996)

report improved reproductive performance for rabbits fed supplemental iron in all parameters measured, and these findings may hint at why Snowshoe Hares target these soils. Images of other mammals from our cameras indicate that the excavation may also be of benefit to others.

Snowshoe Hares in the northern boreal forest normally eat willow (*Salix* spp.), birch (*Betula* spp.), soapberry (*Shepherdia* spp.), and White Spruce (*Picea glauca*) branchlets (Hodges and Sinclair 2003); however, in the study area, most evidence of browse was on Prickly Rose, despite the fact that those species mentioned above appear to be in good supply. We did not detect elevated iron levels in Prickly Rose and therefore do not ascribe the increased iron levels in fecal pellets to this source.

Mahaney et al. (1997) found that 0.15–0.20% of iron in soils consumed by chimpanzees could be extracted with an acid of the same pH as that of the digestive tract, making it a bioavailable iron. Iron in soils could therefore be an important nutritional source for Snowshoe Hares. Black-tailed Jackrabbits in Idaho were reported to have obtained 75% of the iron in their diet from soil consumption (Arthur and Gates 1988). We therefore suggest that increased iron levels in fecal pellets we sampled may be due to consumption of iron-rich aggregate by Snowshoe Hares at the excavation site.

The mean home range size for Snowshoe Hares is ~12.8 ha, with core use areas (50%) of 1.4 ha (de Bellefeuille et al. 2001). A significant difference between the fecal iron levels in the pellets from the excavation site and the pellets from the control far sites indicates that only the Snowshoe Hare pellets collected from within an approximate home range distance from the aggregate showed increased iron levels. This may be attributable to differences in iron levels of plants and or soils that Snowshoe Hares were consuming within these different home ranges, but was beyond the scope of this study to investigate in any detail. If geophagy

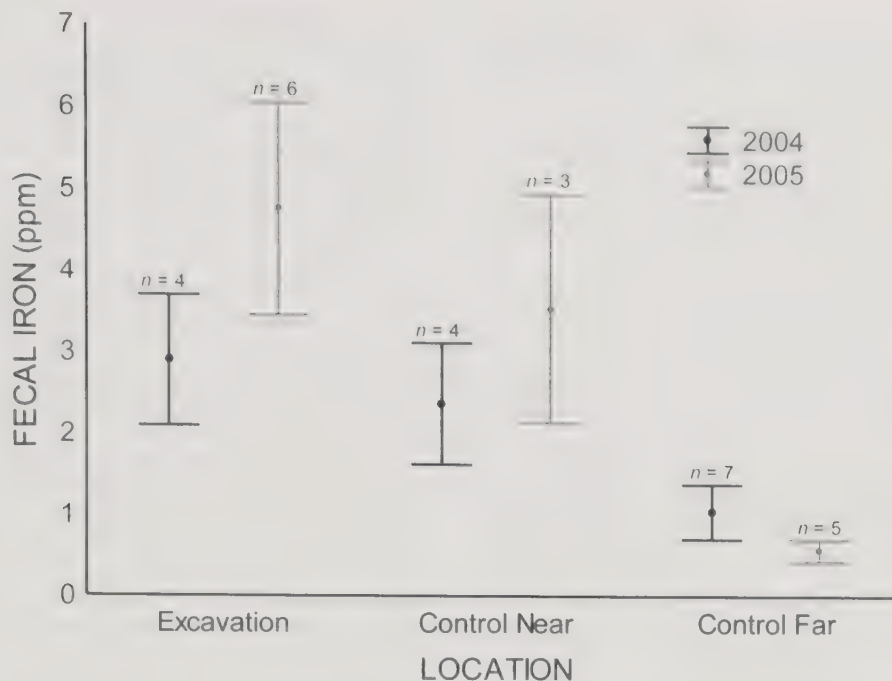


FIGURE 2. Mean (\pm 1 S.E.) iron (II) sulphate concentrations in Snowshoe Hare (*Lepus americanus*) fecal pellet samples collected in February 2004 (black bars) and February 2005 (grey bars) at the mineral excavation site in the John Prince Research Forest, northwest of Fort St. James, British Columbia; near the excavation site (between 1 and 2 km away); and far (2+ km) from the excavation site.

was not occurring, it might be expected that fecal iron levels would have been similar throughout the study area, but of course that would depend on several factors (e.g., rock provinces, soil types) that were not examined.

Because the preferred habitat of Snowshoe Hares is mid-seral stage forests (10–25 years) (Potvin et al. 2005) and the excavation exists in an old-growth forest ~300 m from younger forest stands, it appears that Snowshoe Hares were visiting the location to gain access to the iron-rich soil. Documentation of Canada Lynx at the excavation indicates that there is a potential risk of predation for the Snowshoe Hares that use the site. The fact that the Snowshoe Hares use the site regularly suggests that the site must be relatively important.

At less than 1300 m above sea level, the altitude in the John Prince Research Forest is not considered extreme. Animals at high altitude (>2500 m) may have an increased need for iron to replenish hemoglobin due to increased oxygen demand (Mahaney et al. 1997), but that does not provide a plausible explanation for soil ingestion in this location.

Iron-mineral hunger primarily appears to be a tropical-subtropical phenomenon (Mahaney and Krishnamani 2003), but according to our research it may also occur in north-central British Columbia. Future research will be needed to ascertain more clearly whether the mineral aggregate is being eaten by Snowshoe

Hares. This could be partly accomplished by using newer video camera recording technologies. A less observational approach through destructive sampling of Snowshoe Hares and stomach content analysis could also be performed. Labeling the iron aggregate with a marker or dye that could be definitively identified in fecal pellets might prove useful. Blood samples could be taken from Snowshoe Hares near the excavation site and analyzed for serum iron levels and then compared to levels from Snowshoe Hares in control locations to determine if mineral absorption is occurring from soil ingestion. The mineral and nutritional composition of the complete local Snowshoe Hare diet, including levels of secondary plant compounds, should be determined while also considering the current phase of the population cycle and parasite loads in the area.

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Community-Based Observations of Marine Mammal Occurrences in Groswater Bay, Labrador

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Experienced observers from the community of Rigolet, Newfoundland and Labrador, recorded marine mammal observations at Rigolet on the coast of Labrador from July to September 2012. During this study, a total of nine species of marine mammals were documented. A daily average of 2.6 (range 1–5) marine mammal species were observed, with Harp Seals (*Pagophilus groenlandicus*) and Common Minke Whales (*Balaenoptera acutorostrata*) being the most common. The area is thought to be regionally important for Ringed Seal (*Pusa hispida*) whelping; however, Ringed Seals were not observed in large numbers. Beluga Whales (*Delphinapterus leucas*) were also reported anecdotally, but were less common than the other species, with the possible exception of the Harbour Porpoise (*Phocoena phocoena*). Labrador is experiencing significant industrial growth related to hydroelectric development and offshore oil and gas exploration. These data should aid environmental assessment and environmental effects monitoring and assist researchers in understanding regional marine mammal ecology, including species diversity, seasonal occurrence, and relative abundance.

Key Words: seal, whale, Harp Seal, *Pagophilus groenlandicus*, Common Minke Whale, *Balaenoptera acutorostrata*, Ringed Seal, *Pusa hispida*, Beluga Whale, *Delphinapterus leucas*, Harbour Porpoise, *Phocoena phocoena*, marine mammal, biodiversity, Inuit, Groswater Bay, Lake Melville, Rigolet, Labrador.

Labrador forms the northeast coast of mainland Canada. This coastline is complex, with many islands, islets, fiords, bays, and rivers (Lopoukhine et al. 1978). Even though Labrador represents a sizable proportion of the overall Canadian coastline, very few studies of marine mammal biodiversity and seasonal abundance have been reported for the region. Various researchers have investigated individual seal species in the region, particularly in relation to diet, movement patterns, or contaminants (e.g., Beck et al. 1993; Stenson and Sjare 1997; Oftedal et al. 1996; Kuzyk et al. 2005; Andersen et al. 2009). However, there is much less information on the overall seasonal diversity and occurrence of marine mammals in the region, and much of what is available is dated (e.g., Sergeant and Fisher 1957) or is concerned with historical hunting patterns (e.g., Arkham 1984). Here, we present a community-based survey of seasonal occurrence of marine mammals conducted by Inuit in Rigolet, Labrador.

The region is classified as coastal barrens (Lopoukhine et al. 1978). It is considered to have a high-boreal ecoclimate (Meades 1990*) and a low arctic oceanographic regime (Nettleship and Evans 1985). The community of Rigolet is at the eastern end of the “Narrows,” which is an important marine corridor between Lake Melville and the Labrador Sea (Atlantic Ocean) (Figure 1). The Narrows acts as a pathway allowing the nutrient-rich fresh waters of Lake Melville (a tidal water body) to exchange with the cold, saline waters of the Labrador Sea. The Narrows is also a regionally important shipping lane for the transport of fuel, cargo,

and passengers, although very little information exists with respect to the overall amount of vessel traffic. The Narrows are also thought to be an important movement corridor for several locally important species, including Atlantic Salmon (*Salmo salar*) and the Ringed Seal (*Pusa hispida*). Finally, the area is also thought to provide important habitat for molting Surf Scoters (*Melanitta perspicillata*) (Rao et al. 2009*).

For many generations, local Inuit have observed that this area is highly productive and important for many species of fish, seabirds, waterfowl, and marine mammals, especially during ice-free periods. It is generally assumed that fresh water and organic materials from Lake Melville mix with the salt water of the Labrador Current to create a unique ecological setting that supports regionally high biodiversity and biomass. However, very few studies have investigated the ecosystem immediately surrounding Rigolet, or indeed the larger region of Lake Melville and Groswater Bay. In 2012, the Rigolet Inuit Community Government initiated an observation program to document marine mammal biodiversity and relative abundance during the summer and fall periods. The data could inform regional environmental assessment and ecological monitoring related to industrial activities such as marine shipping, hydroelectric development, and offshore oil exploration.

Methods

For the duration of the study, the field team consisted of two experienced local observers. Both were



FIGURE 1. Study area, including the approximate location of the observation post and the approximate field of view (hatched area). Inset map shows the location of the study area within Labrador.

local Inuit hunters with significant knowledge of marine mammal identification accumulated through a lifetime of land use and harvesting. In addition to this, the observers received supplemental training in the identification of marine mammals and marine mammal behaviour. This included watching videos of various types of behaviour classes (feeding, jumping, spying, etc.) and reviewing guidebooks on various types of marine mammals and their identifying marks. Training was also provided in observation and data recording methods, including the use of field sheets and computer software for data entry. Several categories of behaviour were included on the data sheets, including feeding, jumping, and spying, and these were assigned to each observation as appropriate.

An observation post (NAD 83: 54.180397°N, 58.42513°W) was established on the community waterfront at a height of approximately 3 m above sea level. Local landmarks were used to establish the field of view, which was estimated to be approximately 200 ha in area (Figure 1). Sightings within this area were recorded, but observations outside of the viewing area were not. The location of individual observations was not mapped. Initial sightings were made by eye. When possible, species identification was confirmed using 8 × 42 roof prism binoculars.

Daily observations were conducted between 0900 and 1540 Atlantic Daylight Time inclusive, for a normal program of 6 observation periods of 10 minutes each per day. These were conducted on the hour in the morning (0900, 1000, and 1100) and on the half hour in the afternoon (1330, 1430, and 1530). This program was implemented at least four days per week, from Monday to Friday, for the duration of the study. The study was conducted from 11 July 2012 to 28 September 2012, representing 303 observation periods of 10 minutes each (or 50.5 observation hours) over 52 observation days.

Observations outside of the field of view (see Figure 1) or the predetermined observation periods are referred to in this report as anecdotal observations and were not included in the analyses. If a species was observed one or more times during any given observation period, it was assigned a "1"; if it was not observed, it was assigned a "0".

No effort was made to correct counts based on repeat observations. However, we did post-process the data for presence and absence and subsequently used this information to calculate a daily observation probability. For example, a typical day would have 6 observation periods of 10 minutes each. If a species was observed during only one observation period on a given day, the daily observation probability was 1/6 (0.16667) (if there were fewer than 6 daily observation periods, the denominator was changed as appropriate). For the purposes of reporting, groups of marine mammals are referred to as pods throughout the report. Minitab (version 16) was used for data analyses.

Results

For the period July–September 2012, the automated weather station in the nearby community of Cartwright reported a three-month average temperature of 13.9°C and an average precipitation of 105.5 mm. For the same three-month period, the 1971–2000 Canadian Climate Normals for Cartwright report an average temperature of 10.8°C and an average precipitation of 92.8 mm (Environment Canada Online*). These comparisons suggest that July to September, 2012 was slightly warmer and wetter than average for this section of the Labrador coast. Visibility was generally good throughout the study, even on overcast and rainy days. The study team recorded only one 10-minute observation period as "too foggy to see". In fact, days with high winds were the most problematic, as waves and/or whitecaps made it more difficult to spot marine mammals breaching the water. However, due to strong tides, wave heights above 1 m are less common in the study area than in Groswater Bay or Lake Melville.

In total, eight species were recorded over the course of 303 observation periods conducted over 52 observation days. The team counted a total of 1841 marine mammals (Table 1). Of these, 1015 (55%) were seals and 826 (45%) were whales. Harp Seals (*Pagophilus groenlandicus*) had the highest overall counts (Table 1) and were observed in relatively large pods, known locally as "sculls" (mean 9.6, SD 13.7, $n = 100$). However, Common Minke Whales (*Balaenoptera acutorostrata*) were the most commonly observed species, with an average daily observation probability of 71.9%. Due to their smaller pod sizes (mean 1.0, SD 0.3, $n = 734$), they had the second highest counts (Table 1).

The overall daily probability of seeing a marine mammal (regardless of species) during any 10-minute observation period was estimated to be 88%. A mean of 2.6 (SD 1.2) marine mammal species was observed per day (range 1–5 species/day). Slightly less than 10% ($n = 176$) of all individuals counted were classed as feeding, and the majority of these observations were attributed to whales (e.g., mainly Common Minke Whale lunge feeding). Less than 5% ($n = 72$) of all individuals counted were classed as spying, and these were all attributed to seals (e.g., primarily Harp Seals).

The highest probability of observing Harp Seals occurred in June and August (i.e., a bimodal distribution), with August being the secondary peak and observations generally decreasing with time (Figure 2). The probability of observing Common Minke Whales seemed to increase with time: they had reached peak occurrence by mid-September (Figure 2). Humpback Whales (*Megaptera novaeangliae*) were not observed until late August, but they were observed regularly thereafter until the end of the study (Figure 2). Ringed Seals were not observed in great numbers, and their highest observation probability occurred during the first part of the study (Figure 2).

TABLE 1. Summary of marine mammal observations between 11 July and 28 September 2012. The mean pod size (standard deviation in parentheses) is calculated as the total number of individuals divided by the number of pods observed. The range column indicates the minimum and maximum number of marine mammal pods observed during any given observation period over the course of the survey.

Species ¹	Daily mean observation probability ²	Number of pods observed	Total number of individuals	Mean pod size	Range
Common Minke Whale (Pamiuligak)	0.719	734	765	1.0 (0.3)	1–5
Harp Seal (Kaigulik)	0.205	100	960	9.6 (13.7)	1–60
Humpback Whale (Apvik)	0.151	56	58	1.0 (0.2)	1–2
Ringed Seal (Natsik)	0.069	27	28	1.0 (0.2)	1–2
Bearded Seal (Utjuk)	0.042	8	9	1.1 (0.4)	1–2
Grey Seal (Apa)	0.028	9	9	1.0 (0.0)	-
Harbour Seal (Kasigiak)	0.019	7	9	1.3 (0.8)	1–3
Harbour Porpoise (Nesâtsuk)	0.003	1	3	3	3
Summary		942	1841	1.9 (5.2)	1–60

¹ Inuttitut name in the Rigolet dialect of Labrador Inuttitut shown in parentheses.
² The mean observation probability is the chance of observing a species on any given day averaged over the course of the study and is based on the daily observation probability (see Methods). The daily observation probability, which also factors in the number of observation periods when a species is not recorded, is not directly related to the number of pods or total counts. The observation probability does not sum to 1.0, since, during any given 10-minute observation period, all eight species could be observed and documented (although in practice that did not happen).

In addition to the observations reported above, a small pod of Beluga Whales (*Delphinapterus leucas*), known as Kilalugak by local Inuit, were observed near the community wharf and remained in the area for approximately one week in early July prior to the start of the study. Residents of the community also observed Beluga Whales later in the summer, but not during established observation periods.

Discussion

In terms of observation bias, species closest to the shore were assumed to be the easiest to observe and identify. Likewise, larger species (i.e., whales) were assumed to have higher detection rates than smaller species (i.e., seals), with the possible exception of Harp Seals, which occurred in large pods. It was also assumed that local small vessel traffic, especially speed boats, disturbed all observed species and could have affected the overall detection rates.

We made no effort to correct the number of sightings based on repeated observations, detection bias, or tolerance to disturbance. Therefore, our results should be viewed as indices of seasonal occurrence and relative abundance rather than as population counts. The daily observation probabilities (Figure 2) reduce the inflationary impacts of repeated observations, and they complement the other data (Table 1). For example, ranking the species based on the number of pods ob-

served and observation probability (Table 1) produces a nearly identical rank order.

Within this context, Harp Seals and Common Minke Whales were the most commonly observed species, while Humpback Whales were the next most frequent species. At least one marine mammal species was observed each day (range 1–5), and at least one was observed in approximately 88% of the 10-minute observation periods. These results suggest that overall detection rates were high. About 10% of all observations were classed as feeding; however, actual feeding rates could have been much higher. Events designated as feeding were often associated with Common Minke Whale lunge feeding on observable schools of Capelin (*Mallotus villosus*), which are easily observable because they make a distinct rippling pattern on the surface of the water.

Ringed Seals were not observed in great numbers (i.e., 28 counted), even though the adjacent area of Lake Melville is known by local aboriginal people to be a regionally important area for Ringed Seal whelping. It is possible that Ringed Seals remain resident in Lake Melville year round or that Ringed Seals dispersed from Lake Melville prior to the commencement of the study.

Local elders in North West River (a community situated on the west end of Lake Melville) report that Ringed Seals are rarely observed in Lake Melville dur-

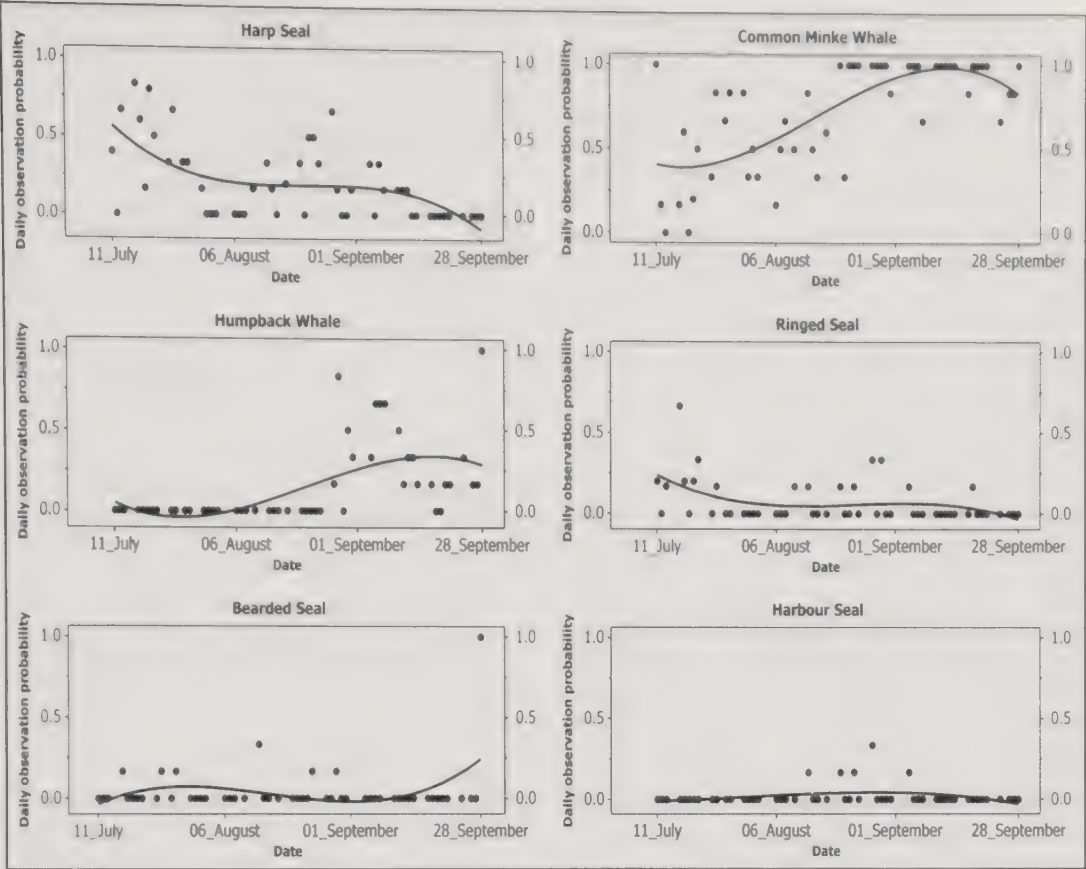


FIGURE 2. Scatter-plots of daily observation probability for Harp Seals (*Pagophilus groenlandicus*), Common Minke Whales (*Balaenoptera acutorostrata*), Humpback Whales (*Megaptera novaeangliae*), Ringed Seals (*Pusa hispida*), Bearded Seals (*Erignathus barbatus*), and Harbour Seals (*Phoca vitulina*) from 11 July to 28 September 2012, arranged by date. The daily observation probability is based on presence and absence data (a typical observation day has six observation periods of 10 minutes each) (see Methods).

ing the summer, compared with early spring, when ice is still present (B. Chaulk, personal communication). In addition, recent unpublished tracking data (B. Sjare, personal communication) suggest that Ringed Seals move in and out of Lake Melville from other areas of coastal Labrador over the course of the ice-free period. This finding is consistent with the movement dynamics of Ringed Seals observed by other researchers (e.g., Kelly et al. 2010).

Harbour Seals (*Phoca vitulina*) are hunted by Inuit in Groswater Bay and occasionally in Lake Melville; however, this species was rarely observed during our study, with only nine Harbour Seals counted. It may be that Harbour Seals do not frequent the area close to the Narrows for various reasons (i.e., sensitivity to disturbance, preferred feeding habitat occurs elsewhere, avoidance of humans). Likewise, Grey Seals (*Halichoerus grypus*) and Bearded Seals (*Erignathus barbatus*) were observed in low numbers, with the Harbour Porpoise (*Phocoena phocoena*) listed as the least frequently observed species.

In addition, a number of Beluga Whales were also observed by the study team, but not during our obser-

vation periods, and are therefore not included in the overall counts. However, to support a better understanding of the overall marine mammal biodiversity, these sightings were included as anecdotal observations. It is not known if these Beluga Whales were affiliated with populations in northern Quebec, the Gulf of St. Lawrence, or elsewhere. However, because of the conservation status of those populations (the Ungava Bay population is designated endangered by the Committee on the Status of Endangered Species in Canada (COSEWIC) and the St. Lawrence estuary population is designated threatened) (COSEWIC 2004*; Hammill et al. 2004; Fisheries and Oceans Canada 2012*), we documented all Beluga Whale sightings. This information may help to delineate their distribution and population trends. In addition to the marine mammals listed here, Polar Bears (*Ursus maritimus*) from the Davis Strait subpopulation are also found in the Labrador region, including Groswater Bay (COSEWIC 2008*). None were observed during this study.

It is unclear how the study area compares with other regions of Labrador in terms of the diversity, relative abundance, and seasonal occurrence of marine mam-

mals. Personal observation (by the lead author) and other sources (e.g., Sjare and Reddin 2002*) suggest that Common Minke Whales and many of the seal species are ubiquitous throughout coastal Labrador. Employing similar methods at other sites along the Labrador coast could provide a better understanding of regional marine mammal ecology, especially with respect to incidence, relative abundance, and diversity.

This study program was relatively cost effective to implement. It required very little in the way of equipment, logistics, or funding other than salaries for the field team. For groups looking to lower costs, a reduced version of this study program with fewer daily observations could be run by a small group of volunteers. Other possible suggestions with respect to study design might include adding a second observation post away from the local community to act as a frame of reference.

In the next decade, the Labrador region is expected to undergo significant industrial development, including but not limited to marine shipping, hydroelectricity, offshore oil exploration, and mining. One of the most imminent large-scale projects in the region is the Muskrat Falls hydroelectric project. Muskrat Falls is located 180 km upstream from the community of Rigolet on the Churchill River. The Government of Newfoundland and Labrador sanctioned the project in December 2012, with major construction commencing in 2013. Should this development proceed, there is the potential for the downstream transport of methylmercury from the reservoir and down-stream nutrient loss as a consequence of regulating spring run-off from the Churchill River via the Muskrat Falls dam site. As a consequence, there could be long-term impacts on the marine ecosystem, and our data could serve as an important baseline for the region.

Acknowledgements

We thank the Rigolet Inuit Community Government and the Tasiujaksoak Trust for funding this project. Thanks are extended to Eldred Allen and Bryn Wood for assisting in figure production and to Ellen Adams for reviewing the Inuit species names. Thanks to Thomas Jung, Martha MacDonald, Morgon Mills, Becky Sjare, John Trehune, and Jane Watson, whose review comments greatly improved the quality of this paper.

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The Ocean Pout, *Zoarces americanus*, and the Ocean Sunfish, *Mola mola*: Additions to the Marine Ichthyofauna of the Lower Saint John River System, New Brunswick, with a Summary of Marine Fish Reported from the Estuary

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McAlpine, Donald F. 2013. The Ocean Pout, *Zoarces americanus*, and the Ocean Sunfish, *Mola mola*: Additions to the marine Ichthyofauna of the lower Saint John River system, New Brunswick, with a summary of marine fish reported from the estuary. *Canadian Field-Naturalist* 127(1): 38–43.

Recent records for the Ocean Pout, *Zoarces americanus* (collected 11 February 2011), and the Ocean Sunfish, *Mola mola* (photograph taken 24 June 2012), in the lower Saint John River system, New Brunswick, add to the list of marine fishes reported from this oceanographically unique estuary system. A total of 62 species of strictly freshwater, anadromous, catadromous, and marine fishes have now been recorded in the Saint John River system, with 49 of these in the Saint John River *sensu stricto*. The Acadian Redfish, *Sebastes faciatius*, a species assessed as threatened by the Committee on the Status of Endangered Wildlife in Canada, appears to be among these. While strictly marine fishes may contribute relatively little to the over-all biomass of fishes in the Saint John River system, marine species account for 30.6% of the biodiversity of fishes in the river to date. This suggests that marine fishes may be a more significant component of the ichthyofauna of the lower Saint John River system than is generally recognized.

Key Words: Ocean Sunfish, *Mola mola*, Ocean Pout, *Zoarces americanus*, marine fishes, Saint John River, Kennebecasis River, Kennebecasis Bay, estuary, New Brunswick.

The Saint John River, 673 km in length, drains a basin of 55,110 km² and discharges into the Atlantic Ocean (Bay of Fundy) at a rate of 1110 m³/second (Cunjak and Newbury 2005). It is the longest river in Atlantic Canada. Matthew (1894) was one of the earliest to comment scientifically on the peculiarities of this river, particularly at its outlet. The oceanographic features of the Saint John River estuary and the estuary of its tributary, the Kennebecasis River, are unique. Rock sills at the mouth of each river control the flow of water in and out of the estuaries (Trites 1960). In Kennebecasis Bay (maximum depth 62 m) (Metcalf et al. 1976) this produces a two-layered system with brackish water at the surface and a deep saline layer. In the Saint John River estuary, a well-mixed body of brackish water is present near the mouth and downstream of the confluence of the Kennebecasis River and the Saint John River. The salinity of the deep layer in the Kennebecasis River estuary remains relatively constant at 21–23 ppt, while the surface layer is reported to vary from 0–10 ppt (Trites 1960). Exceptional tidal amplitude in the adjacent Bay of Fundy produces strong currents at the mouth of the Saint John River that alternate in direction daily at ~6 hour intervals.

These unique conditions and high estuarine salinities have allowed fishes normally restricted to marine waters to penetrate the river mouth either permanently or periodically. Among previous reports are 17 fishes normally considered to be strictly marine. This list does not include essentially marine species considered estuarine-dependant (Scott and Scott 1988; Day et al.

1989), such as the Atlantic Silverside, *Menidia menidia*, or the Atlantic Tomcod, *Microgadus tomcod*, both not uncommon in the lower river (Huntsman 1922; Squires and Gorham 1967; Meth 1971). Here I add recent observations of the Ocean Pout, *Zoarces americanus*, and the Ocean Sunfish, *Mola mola*, to the list of marine fishes reported from the estuary of the lower Saint John River system. I also summarize marine fish records from the Saint John River system to date and comment on the contribution of marine fishes to the over-all ichthyological diversity of the estuary.

On 11 February 2011 Joanne Lambert and Herb Loe-man, using shrimp as bait, took an Ocean Pout, *Zoarces americanus*, of 293 mm total length, by hook and line while ice fishing adjacent to the Millidgeville ferry terminal on Kennebecasis Bay, Saint John (45.33°N, -66.07°W) (Figure 1). Hydrographic charts show water depth in the area of capture as 4–9 m. The specimen is now deposited in the New Brunswick Museum fish collection (catalogue no. 2324).

On 24 June 2012 Rebekah Johansson and Gerry McNulty were walking the shoreline area of Indian-town (lower Main Street) in Saint John. The area provides a clear view of the Saint John River estuary above the Reversing Rapids looking towards Milford. They were startled to see a large fin protruding above the water surface about 100 m offshore. The fin remained visible for ~3 minutes while Johansson, equipped with a camera with a 72–300 mm zoom lens took a photograph (Figure 2). The photo shows a single, dull grey, fin in the middle of the estuary channel (45.276°N,

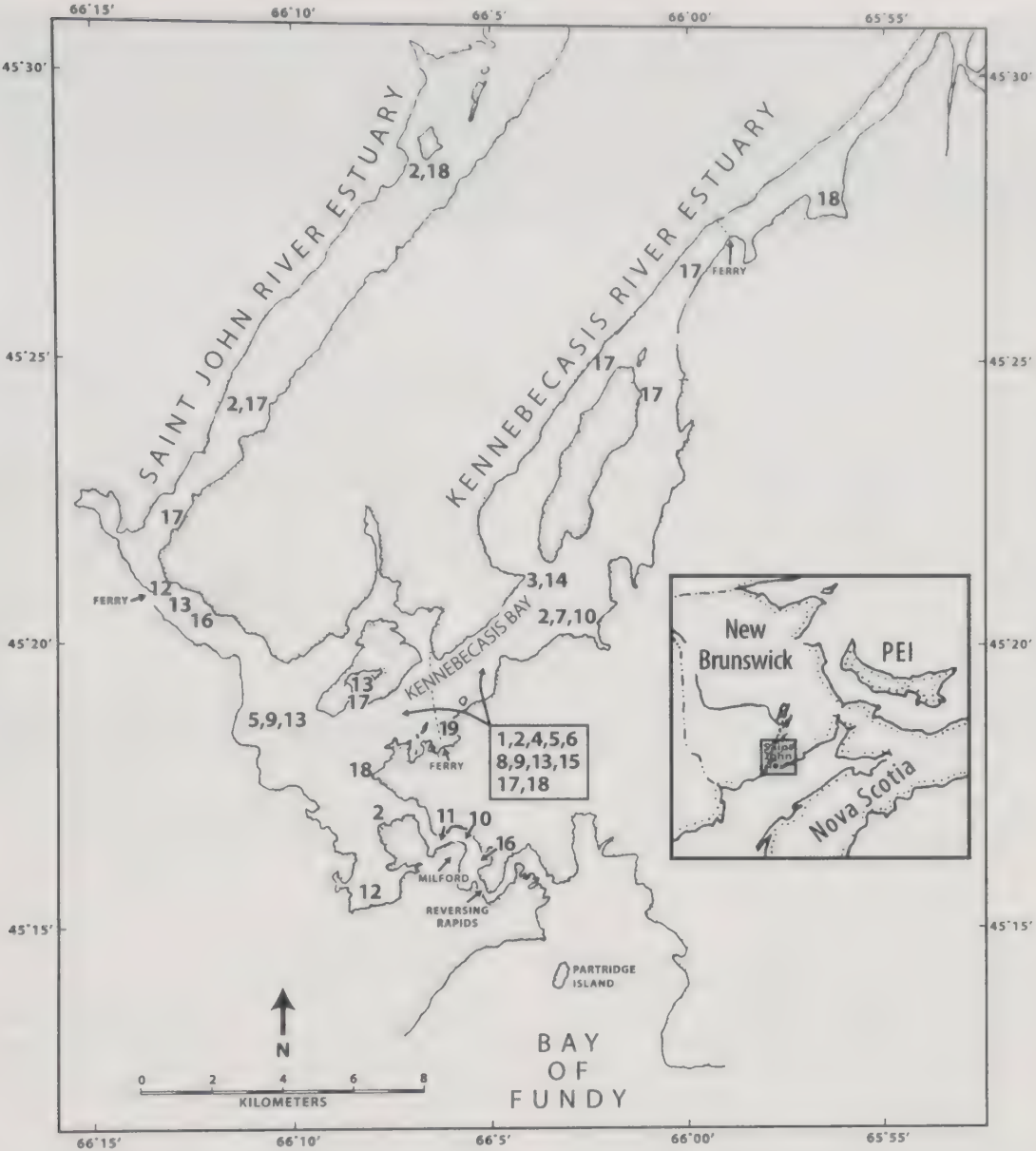


FIGURE 1. The lower Saint John River system. Numbers 11 and 19 mark the locations of the *Mola mola* and *Zoarces americanus* records, respectively, reported in the text. Other numbers correspond to the locations of previous reports of marine fishes listed in Table 1.

June June -66.097°W). The colour, slow movement (essentially stationary from a distance), and maximum height/width ratio of =1.4 for this fin (taken from the photo) distinguish it as that of an Ocean Sunfish, *Mola mola*.

On the basis of line drawings provided in Castro (1983), Scott and Scott (1988) and Compagno et al. (2005) height to width ratios calculated for large sharks reported from the Atlantic region are much lower (0.55–0.94). Male Killer Whales (*Orcinus orca*) have a high, similarly shaped dorsal fin (the female has a smaller, distinctly falcate dorsal fin), but male Killer Whales are very rare in the Bay of Fundy (Gaskin 1997). While the height to width ratio of the dorsal fin

of the Ocean Sunfish may overlap with that of the male Killer Whale, the dorsal fin of the male Killer Whale is black and smooth (not grey and dull) and relatively more broad-based. More significantly, Killer Whales are very active, with surfacing behaviour including a sequence of events — head raised, blow, dorsal fin, and roll of the peduncle (Watson 1981); (L. Murison, personal communication to DFM) — that were noticeably absent in the estuary.

Discussion

Zoarces americanus is a benthic fish of frequent occurrence in the Bay of Fundy from the intertidal to a depth >180 m (Scott and Scott 1988). Clemens and

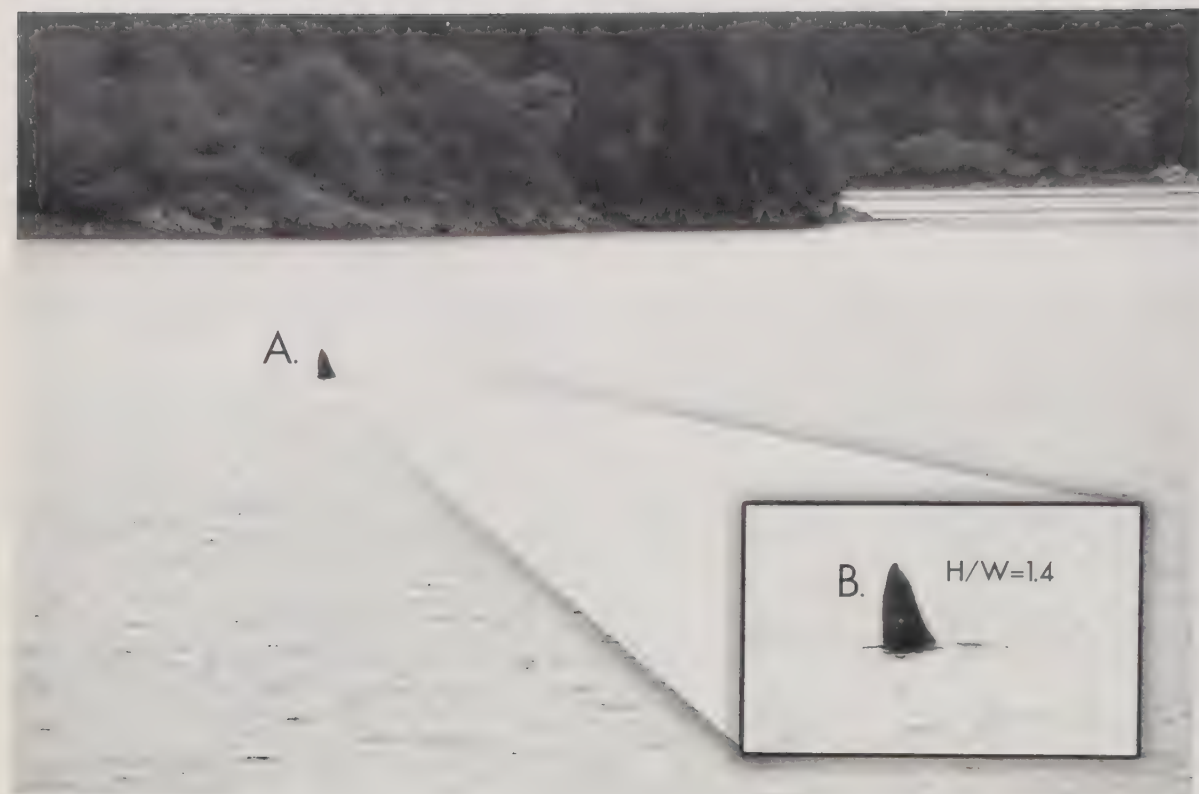


FIGURE 2. Photograph of a *Mola mola* dorsal fin as observed in the lower Saint John River estuary on 24 June 2012. A is the photograph as taken. Inset B has been digitally enhanced only to improve resolution upon enlargement. H/W = ratio of dorsal fin height to width. Photo: courtesy of R. Johansson.

Clemens (1921) reported *Z. americanus* (as *Z. anguilaris*) from 9.7 km (6 miles) up the St. Croix River. The growth curve presented in Clemens and Clemens (1921) suggests that the specimen captured in the Saint John River estuary on 11 February 2011 was a juvenile of ~4.5 years of age. The species is most abundant on hard and semi-hard substrates, rather than mud (Scott and Scott 1988), suggesting that the mud-bottomed estuary may provide only marginal habitat for Ocean Pout or is perhaps most attractive to juveniles. Whether the Saint John River estuary supports a resident population of this species is unknown, although in the Bay of Fundy the Ocean Pout is reported to occupy deeper waters during the winter months, normally leaving rivers and bays and returning in late April (Clemens and Clemens 1921).

Considered a pelagic species, the Ocean Sunfish is a summer visitor to eastern Canadian waters, where it is believed to feed mainly on jellyfish, comb-jellies, crustaceans, molluscs and brittlestars (Scott and Scott 1988), but see Syväranta et al. (2012). Migrations inshore are unpredictable, but in 2012 the species was observed with unusual frequency from whale-watching boats in the Bay of Fundy (L. Murison, personal communication to DFM) and a juvenile individual (< 1 m total length) became fatally stranded on coastal

mud flats near Saint John (New Brunswick Museum fish collection no. 2344).

Fraser-Brunner (1951) and Schwartz and Lindquist (1987) have suggested that individual Ocean Sunfish observed at the surface or inshore are ill or stressed. More recent hypotheses explaining surface activity by this species propose thermal recharging and/or symbiotic parasite removal by fishes or birds (Abe and Sekiguchi 2012). Health status of the *M. mola* observed in the Saint John River estuary on 24 June 2012 is unknown. Although the Ocean Sunfish is an active swimmer capable of highly directional movement (Pope et al. 2010) the individual reported here from the Saint John River may have been swept into the estuary with the rising tide. Prey species that might attract *M. mola* are not believed to be present in the estuary. Examination of the shoreline in the background of Figure 1 suggests the photo was taken at near-high tide or high tide.

Although Adams (1873) noted the presence of the White Hake, *Urophycis tenuis* (incorrectly reported as *Merluccius albidus*); (also reported as *U. chuss* by Trites 1960 and Meth 1971) in the lower Saint John River system, Huntsman (1922) appears to have been the first to comment on the unique conditions leading to the presence of otherwise marine fishes in the lower

part of the river. Since then, Squires (1967) and Meth (1971) have provided compendia of the marine fishes observed in the Saint John River estuary and such can also be extracted from Gorham (1970). Table 1 lists all records of marine fishes recorded to date from the Saint John River estuary system. Cunjak and Newbury (2005) and Curry and Munkittrick (2005) report that 36 fish species occur in the [middle and upper] Saint John River, but as early as 1936 Rogers reported 47 fish species as present in the Saint John and tributaries (plus two species now considered to be in error). Meth (1971) reported 54 species in the lower river system.

Currently, including the new records reported here, 62 species of strictly freshwater, anadromous, catadromous and marine fishes have been assessed as occurring in the Saint John River system, with 49 of these in the Saint John River *sensu stricto* (Rogers, 193; Meth 1971; Burns 1976*; Stoeck et al. 1999; Hood and Stoeck 2005). While strictly marine fishes may contribute relatively little to the over-all biomass of fishes in the Saint John River system, marine species account for

30.6% of the biodiversity of the fishes reported from the river to date

The known distribution of marine fish records in the estuary has been significantly influenced by the location of (past) commercial fishing operations, scientific interest in the oceanographic features of Kennebecasis Bay, and a concentration of ice-fishing activities at public wharves. Since the 1970s there has been a significant decline in commercial fishing activity in the Saint John River system and very limited commercial fisheries continue (Cunjak and Newbury 2005).

Unfortunately, only half of the marine fish reports from the estuary summarized here can now be verified by reference to specimen material. Rogers (1936), Trites (1960) and Squires (1967) all reference unidentified marine fishes from the estuary. Rogers (1936) relates (with some skepticism) a fisherman reporting taking a specimen of the Barndoor Skate, *Dipturus laevis*, measuring “about six feet [1.8 m] across the wings” in Kennebecasis Bay.

TABLE 1. Species of marine fishes recorded from the Saint John River and Kennebecasis River estuaries. Locations are plotted on Figure 1. Where records are supported by specimens, New Brunswick Museum fish catalogue numbers are provided.

Species ¹	Estuary	Month or season	Source and specimen no.
1. <i>Amblyraja radiata</i>	Kennebecasis River	?	Gorham (1970)
2. <i>Cyclopterus lumpus</i>	Kennebecasis River/ Saint John River	January–February; June	Squires (1967); 23, 356, 621, 1078, 1090, 1091, 1092, 2102
3. <i>Enchelyopus cimbrius</i>	Kennebecasis River	June	Burns (1976*)
4. <i>Dipturus laevis</i>	Kennebecasis River	?	Rogers (1936)
5. <i>Gadus morhua</i>	Kennebecasis River/ Saint John River	May–December	Rogers (1936), Trites (1960); 1121
6. <i>Hemitripterus americanus</i>	Kennebecasis River	Winter	Rogers (1936)
7. <i>Hippoglossus hippoglossus</i>	Kennebecasis River	March	Squires (1967); 97
8. <i>Leucoraja ocellata</i>	Kennebecasis River	?	Huntsman (1922)
9. <i>Limanda ferruginea</i>	Kennebecasis River/ Saint John River	August–October	Meth (1971)
10. <i>Lophius americanus</i>	Kennebecasis River/ Saint John River	?	Squires (1967), Gorham (1970); 568
11. <i>Mola mola</i>	Saint John River	June	This note
12. <i>Peprilus triacanthus</i>	Saint John River	August/summer	Gorham (1970); 558, 1059
13. <i>Pseudopleuronectes americanus</i>	Kennebecasis River	May–August	Burns (1976*); 107, 411, 970, 990
14. <i>Scophthalmus aquosus</i>	Kennebecasis River	July	Burns (1976*)
15. <i>Sebastes fasciatus</i>	Kennebecasis River	May–January	Rogers (1936), Trites (1960), Squires and Gorham (1966); 106
16. <i>Squalus acanthias</i>	Saint John River/ Kennebecasis River	?/November	Huntsman (1922), Rogers (1936), Gorham (1970); 734
17. <i>Syngnathus fuscus</i>	Saint John River/ Kennebecasis River	January–September	Squires and Gorham (1967); 275, 1042, 1131, 1808, 1809, 2278, 2345
18. <i>Urophycis tenuis</i>	Saint John River/ Kennebecasis River	March–December	Adams (1873), Meth (1971), Burns (1976*); 560, 861
19. <i>Zoarces americanus</i>	Kennebecasis River	February	This note; 2324

¹Numbers refer to locations on Figure 1.

Rogers (1936) and Trites (1960) reported the Redfish, *Sebastes marinus*, at a time when a single name was applied to a group of fishes now considered to consist of at least three species: *S. fasciatus*, *S. norvegicus*, and *S. mentella*. Squires and Gorham (1966) report *S. marinus mentella* from the estuary, but Scott and Scott (1988) suggested it was “doubtless” the Acadian Redfish, *S. fasciatus*, a shallow-water inshore species and the only *Sebastes* recorded in the Bay of Fundy (Committee on the Status of Wildlife in Canada 2010*). I have assigned the name *S. fasciatus* to all *Sebastes* from the estuary, but it is worth noting that in some areas off eastern Canada all three species can be taken together in the same trawl net (Scott and Scott 1988); that a morphologically and genetically distinct population of *S. fasciatus* is present in fiord-like Bonne Bay, Newfoundland (Committee on the Status of Wildlife in Canada 2010*); and the specimens of *Sebastes* from the Saint John River estuary have not been examined in the light of current nomenclature. *Sebastes fasciatus* has been designated as a threatened species by the Committee on the Status of Endangered Wildlife in Canada (Committee on the Status of Wildlife in Canada 2010*).

While rising sea-levels predicted for eastern Canada (Shaw et al. 1998) may increase the frequency of marine fishes in the lower Saint John River in the future, the occurrences summarized here suggest that marine fishes have been, and continue to be, a more significant component of the current ichthyofauna of the lower Saint John River than is generally recognized.

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Suspected Selective Herbivory of Bioenergy Grasses by Meadow Voles (*Microtus pennsylvanicus*)

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Highly productive native and non-native perennial grasses are being grown for bioenergy purposes in North America, and ecological risks of their large-scale production are being assessed to inform breeding and management practices. Giant Miscanthus (*Miscanthus × giganteus*) and Switchgrass (*Panicum virgatum*) were introduced into an old-field habitat in Guelph, Ontario, in 2012. Seedlings of these species suffered severe selective herbivory, being severed at the plant base by an unknown herbivore. We therefore performed a live-trapping survey and mark-recapture analysis of the small mammal community in 2012 to identify the probable herbivore and estimate its population density. Meadow Voles (*Microtus pennsylvanicus*) were the most abundant herbivore in the area, with an estimated population of 265 individuals/ha, a relatively high density. This and other evidence indicate that Meadow Voles were likely responsible for herbivory of >80% of the transplants. Such herbivory could have a substantial effect on the establishment and survival of these grasses, suggesting that future crop breeding programs and ecological risk assessments should take this into consideration.

Key Words: bioenergy, herbivory, invasion, Meadow Vole, *Microtus pennsylvanicus*, *Miscanthus × giganteus*, *Miscanthus × giganteus* ‘Illinois’, *Miscanthus × giganteus* ‘Nagara’, *Miscanthus × giganteus* ‘Amuri’, *Panicum virgatum*, Switchgrass, *Panicum virgatum* ‘cave-in-rock’, old field, Ontario.

A number of highly productive perennial grasses are currently under development in North America for large-scale agricultural production for bioenergy purposes (Lewandowski et al. 2003; Vermerris 2008). Some of these species are native to North America, whereas others are introduced. For example, cultivars of native tallgrass prairie species such as Switchgrass (*Panicum virgatum*) that were previously developed as forage crops are now being evaluated for biomass production (McLaughlin and Kszos 2005; Dohleman et al. 2012). Similarly, there are several breeding programs and biomass production trials for Asian *Miscanthus* species for improvement as bioenergy crops (Clifton-Brown et al. 2001; Pyter et al. 2009; Dohleman et al. 2012). In addition, various assessments are underway throughout the potential North American cultivation area of these crops to determine ecological risks associated with their large-scale production (e.g., Barney and DiTomaso 2010; Anderson et al. 2011).

In one such study to evaluate the potential effects of these species on local biodiversity (in the event that they escape production fields), one Switchgrass cultivar and three *Miscanthus × giganteus* cultivars were transplanted into an old-field habitat at the University of Guelph Turfgrass Institute in Guelph, Ontario, in spring 2012. Two days after the *Miscanthus* cultivars were planted, selective herbivory of some of the transplants was noted. The stems of these plants had been severed at an angle close to the base, and the top of the plant was usually left beside the stem. Two weeks after the Switchgrass was planted, 80.6% (187 of 232) (HAH, unpublished data) of those transplants had suffered complete herbivory: the plants were severed near

the base of the stem and the top of the plant was usually removed. Most of the surrounding plants of the local vegetation remained intact. This selective herbivory continued throughout the summer and autumn.

By autumn 2012, 80.0% (557 of 696) of the *Miscanthus* transplants and 92.7% (215 of 232) (HAH, unpublished data) of the Switchgrass transplants had experienced mortality that was attributed to the observed herbivory. In addition, a notable proportion of transplant locations showed signs of digging, with Switchgrass roots removed and *Miscanthus* rhizomes showing evidence of chewing. We also observed abundant rodent feces and grass tunnels or runways. Such unusual and extreme selective herbivory of these species has not been noted before, and it could have implications for the establishment of these crops as well as any possible invasion into novel habitats.

Herbivory by small mammals can dramatically affect plant survival and recruitment and the resulting plant composition and diversity in old fields (e.g., Howe and Brown 1999; MacDougall and Wilson 2007; Parker et al. 2010), particularly when population densities of small mammals are high (Howe et al. 2002). Indeed, Parker et al. (2010) recorded 71% (2699 of 3808 plants) mortality of Common Evening Primrose (*Oenothera biennis*) transplants caused by Meadow Vole (*Microtus pennsylvanicus*) herbivory in an experimental old-field habitat; signs of stem girdling and root consumption were considered to be indicators of Meadow Vole herbivory (Parker et al. 2010).

As a result of observing such unexpected herbivory of the biofuels grasses in Guelph, we performed two additional studies. In mid-summer 2012, we transplant-

ed seedlings of *M. × giganteus* cultivars and seedlings of a *P. virgatum* cultivar inside and outside small mammal exclosures to follow their survival. In late autumn to early winter, we performed a live-trapping survey and mark-recapture analysis of the small mammal community within the transplant experiment to determine the species composition, abundance, and density of small mammals. Our aim was to identify the potential herbivore of the experimentally introduced grasses using this indirect evidence.

Methods

Study site

The study area was located at the University of Guelph Turfgrass Institute in Guelph, Ontario (43°32'56"N, 80°12'39"W), in a decommissioned apple orchard that has been maintained in an old-field succession by occasional mowing since approximately 1992 (Yurkonis et al. 2012). The old field was composed primarily of non-native grasses such as Kentucky Bluegrass (*Poa pratensis*), Smooth Brome (*Bromus inermis*), Quackgrass (*Elymus repens*), and Reed Canary Grass (*Phalaris arundinacea*). It included forbs such as vetches (*Vicia* spp.), thistles (*Cirsium* spp.), goldenrods (*Solidago* spp.), and asters (*Aster* or *Symphyotrichum* spp.).

The study area consisted of eight blocks. Each block comprised 16 experimental plots (5 × 5 m each) for a total of 128 plots, with a 1-m laneway between plots that was mowed two to three times during the summer. The experiment covered a total of 0.46 ha, including a 1-m buffer around each block. Each of the 16 plots within a block received transplants of one of four bioenergy grasses at one of four densities in a randomized design. The grasses were *M. × giganteus* cv. 'Illinois', 'Nagara', and 'Amuri' and Switchgrass (*P. virgatum* cv. 'cave-in-rock'). They were planted at densities of 0 (control), 4, 9, and 16, evenly spaced within a 4 × 4 m area central to each plot. This provided a 1-m buffer between transplants and the laneway. Ninety-six plots received transplants and 32 plots served as controls.

Miscanthus transplants were started from rhizomes (New Energy Farms, Leamington, Ontario) in the greenhouse and hardened off outdoors for one week prior to transplanting. Switchgrass transplants were started from seed (Ernst Conservation Seeds, Meadville, Pennsylvania) in the greenhouse and hardened off outdoors for two weeks prior to transplanting. *Miscanthus* was transplanted into the old field in mid-May 2012, and Switchgrass was transplanted in early June 2012. Care was taken to minimize disturbance of the local vegetation. Transplant survival and confirmed or putative cause of death were determined several times throughout the growing season, with a final census in autumn 2012.

Small mammal exclosures

Subsequent to the unexpected herbivory of transplanted biofuels grasses, we performed a small mam-

mal exclosure study in the same old-field habitat to examine the survival of transplants that had and had not been exposed to small mammals. Thirty-seven small mammal exclosures were installed in a completely randomized design in mid-summer 2012, and an equal number of controls (i.e., no exclosure) were established. Exclosures comprised solid PVC pipe (15 cm in diameter) inserted 10 cm into the ground, with 5 cm above-ground, and hardware cloth (1.3 cm mesh) fitted around the pipe aboveground to 30 cm in height. Exclosure tops were left open to allow for plant growth.

A single seedling was transplanted into each exclosure or control on 12 June 2012 for *Miscanthus* and on 16 July for Switchgrass. Because of the availability of transplants, 9 exclosures and 9 controls received the 'Illinois' cultivar, 7 exclosures and 7 controls received 'Nagara', and 6 exclosures and 6 controls received 'Amuri'; 15 exclosures and 15 controls received Switchgrass. Seedlings were watered after transplanting to reduce the risk of mortality due to drought. Transplant survival was assessed periodically until late autumn.

Small mammal survey

We used live-trapping and a mark-recapture analysis to census the small mammal community at the study location and determine the probable herbivore of the experimentally introduced grasses. Small mammals were live-trapped between 8 November and 13 December 2012 once trapping protocols and procedures were approved by the University of Guelph Animal Care Committee (protocol eAUP 1638) and trained personnel were available. One collapsible Sherman live-trap was placed within each of the 128 experimental plots so that traps were set at 6-m intervals. The eight blocks of the study area were divided into two sets, such that blocks 1 through 4 were trapped for three consecutive nights and blocks 5 through 8 were trapped for the following three consecutive nights.

Trapping methods followed field protocols developed by Falls et al. (2007). Traps were baited with cotton bedding, black sunflower seeds (*Helianthus* spp.), and one mealworm (*Tenebrio molitor*). Traps were set at dusk and checked at dawn the following morning. Shrews were identified to genus and immediately released to minimize mortality due to trapping and handling stress. All other animals were identified to species, sexed, and given a numbered monel metal ear tag (National Band and Tag, Newport, Kentucky) upon first capture.

Statistical analysis

For the exclosure experiment, we tested whether the probability of mortality due to herbivory differed between exclosures and controls (no exclosures) for transplants of each cultivar using χ^2 analysis with Yates correction.

For the small mammal survey, we standardized our estimates of small mammal abundance as the number of individuals captured per 100 trap-nights. Our block

study design also provided the spatial coverage desirable for a Schnabel mark-recapture analysis to allow the estimation of population density (Ryan 2011). This analysis assumes that individuals have the same probability of being captured in the first and subsequent samples, that the population is closed, that no marks fall off animals between captures, and that marks are correctly identified by the researcher.

We tested for differences in the number of small mammal captures among species/cultivars (plot types) and planting densities using generalized linear models with a Poisson probability distribution and log link function. We also tested for differences in captures between control plots that received no transplants and the combination of all plots that received transplants (vegetation type) using the same statistical procedure. The first model included block, plot, density, and plot \times density as fixed factors. The second model included block and vegetation type as fixed factors. These analyses were performed using SPSS Statistics 20 software (IBM).

Results

In the enclosure experiment, the number of transplants that died due to herbivory differed between late summer and late autumn (Table 1). By late summer,

only one Switchgrass transplant and no *Miscanthus* transplants had experienced mortality due to herbivory when small mammals were excluded, whereas all Switchgrass transplants and the majority of *Miscanthus* transplants (5 of 6, 8 of 9, and 5 of 7 transplants per cultivar) experienced mortality when small mammals were present ($P < 0.05$, Table 1).

However, by mid-October, stems within the enclosures began to be severed close to the base in a manner similar to those planted in the larger field experiment, indicating that herbivory occurred into the autumn. No holes were apparent in the soil, so the cages were not entered from below, and the cages were too narrow and tall for any animals larger than a small squirrel to enter from the top. In addition, several rhizomes had been partially excavated and showed evidence of having been chewed, similar to those in the larger field experiment. We thus surmise that small rodents learned to climb the cages to enter the enclosures.

Three species were caught during the live-trapping session: the Meadow Vole, the Northern Short-tailed Shrew (*Blarina brevicauda*), and a deer mouse (*Peromyscus* sp.). Meadow Voles far outnumbered any other species captured in the study area, with 4 times the total number of captures/recaptures of other species (Table 2).

TABLE 1. Total numbers of transplants that suffered mortality due to herbivory inside and outside small mammal enclosures at two census times in an old-field bioenergy grass transplant experiment at the University of Guelph Turfgrass Institute in Guelph, Ontario, in 2012. n is the total number of transplants in each treatment level. χ^2 critical value at $df = 1$, $\alpha = 0.05$ is 3.841. χ^2 values for *Miscanthus* \times *giganteus* cultivars ‘Illinois’ and ‘Nagara’ could not be determined at the final census date (16 October) due to complete mortality of these cultivars after herbivores learned to climb into the enclosure cages.

Census date	Treatment	Total number of plants consumed			
		Switchgrass ‘cave in rock’ ($n = 15$)	<i>Miscanthus</i> \times <i>giganteus</i> cultivars		
			‘Amuri’ ($n = 6$)	‘Illinois’ ($n = 9$)	‘Nagara’ ($n = 7$)
8 August	Enclosure	1	0	0	0
	No enclosure	15	5	8	5
	χ^2	22.63*	5.486*	11.03*	4.978*
16 October	Enclosure	1	2	9	7
	No enclosure	15	6	9	7
	χ^2	22.63*	3.375	–	–

* $P < 0.05$

TABLE 2. Summary of the number of individuals, total number of captures, standardized estimate of abundance, and estimate of population density (standard deviation in parenthesis) for species of small mammals caught in an old-field bioenergy grass transplant experiment at the University of Guelph Turfgrass Institute, Guelph, Ontario, in 2012. Population density of the Northern Short-tailed Shrew could not be estimated because Northern Short-tailed Shrews were not tagged (see Methods). Population density of the deer mouse could not be estimated because only one individual was captured during live-trapping.

Species	Total number of captures	Total number of individuals captured	Standardized estimate of abundance (per 100 trap-nights)	Population density (individuals/ha)
Meadow Vole	76	49	7.9	265 (14)
Northern Short-tailed Shrew ¹	19	–	1.9	–
Deer mouse	1	1	0.1	–

¹To minimize mortality due to handling stress, Northern Short-tailed Shrews were not marked; therefore, only the total number of captures is known.

Trapping success varied across the study period, ranging from 0 to 12 captures of Meadow Voles during a single trapping session. Using a Schnabel mark-recapture analysis, we estimated Meadow Vole population density as 275 individuals/ha (95% confidence intervals (CI) 273; 285 individuals/ha) for blocks 1 through 4 and 255 individuals/ha (95% CI 240; 264 individuals/ha) for blocks 5 through 8. Averaging these two estimates gives a mean Meadow Vole population density estimate of 265 (SD 14) individuals/ha for the study area during November and December 2012.

Northern Short-tailed Shrew and deer mouse population densities could not be estimated because Northern Short-tailed Shrews were not marked (following animal care protocols), and only one deer mouse was captured during the entire trapping session.

There was no significant difference in the number of Meadow Vole captures among plot types or planting densities (Table 3). There was also no significant difference in the number of Meadow Vole captures among control and transplanted plots (vegetation type, Table 3). The block effect was not significant in either analysis.

Discussion

By the time of trapping, the majority of transplants had been removed aboveground by herbivory. However, 24% of the 96 plots in the initial experiment that received transplants where the trapping was subsequently performed had 1–5 live transplants at the time of the last census in mid-October (HAH, unpublished data). In addition, *Miscanthus* rhizomes were present belowground and also presented a feeding opportunity for small mammals at the time of live-trapping.

At the time of trapping, the Meadow Vole was by far the most abundant species in the study area. It is primarily a herbivore, consuming mainly green shoots, with seeds and roots becoming important in winter (Lindroth and Batzli 1984). The species is known to dig up rhizomes and cut off both native and agricultural plants at the base to consume the nutrient-rich seeds (Reich 1981). In contrast, we captured few deer mice (one), which consume mainly insects, seeds, and fruits, with green plant matter forming only a small portion of the diet (Hamilton 1941). We also captured a small number of Northern Short-tailed Shrews; however, this species consumes mainly invertebrate and vertebrate prey, with plant matter such as seeds and berries composing only a small portion of the diet (Hamilton 1930, 1941; Whitaker and Ferraro 1963).

The patterns of herbivory observed in the study area were similar to those noted previously for Meadow Voles (i.e., stem girdling and root excavation and consumption) (Howe et al. 2002; Parker et al. 2010). We also observed abundant grass tunnels, which are indicative of the presence of Meadow Voles (Caras 1967; Reich 1981). Although we do not have direct evidence

TABLE 3. Results of two generalized linear models for frequency of Meadow Vole (*Microtus pennsylvanicus*) captures in an old-field bioenergy grass transplant experiment at the University of Guelph Turfgrass Institute in Guelph, Ontario, in 2012. Top: Among plots (four cultivars: *Miscanthus > giganteus* cv. ‘Illinois’, ‘Nagara’, and ‘Amuri’, and *Panicum virgatum* cv. ‘cave-in-rock’) and planting densities (four densities: 0 (control), 4, 9, and 16). Bottom: Among vegetation types, i.e., control (no transplants) and transplants of the four cultivars combined (as above).

Source	Likelihood ratio χ^2	df	P value
Block	5.876	7	0.55
Plot	1.291	3	0.73
Density	0.845	3	0.84
Plot \times density	10.20	9	0.34
Block	4.082	7	0.77
Vegetation type	0.505	4	0.97

such as infra-red video of consumption of transplants or rhizomes or herbivore stomach content analysis, our observations and live-trapping data support the conclusion that Meadow Voles were the most likely herbivore of the *Miscanthus* and Switchgrass seedlings that were transplanted into the old-field habitat.

Meadow Vole population densities can vary dramatically among geographic locations, seasons, and habitats (Banfield 1974; Boonstra et al. 1998). In old-field habitat, Meadow Vole population densities average between 37 and 111 individuals/ha, but in peak years, they can reach in excess of 369 individuals/ha (Banfield 1974). Meadow Voles are active throughout most of the year, and population densities generally are at a minimum in late winter to early spring and then peak in late summer to early autumn (e.g., Johnson and Johnson 1982; Krebs and Wingate 1985).

In comparison with previous studies in old-field habitat (Banfield 1974), our estimate of 265 individuals/ha is a relatively high population density for the season in which these data were collected. This suggests that the population density of Meadow Voles in the previous summer (i.e., summer 2012) might have been exceptionally high or rapidly increasing, resulting in the rates of herbivory documented in this experimental grassland (HAH, unpublished). Additional live-trapping and experimental transplanting in years of differing Meadow Vole population density would indicate whether there is a lower population density threshold of Meadow Voles that would allow for increased transplant survival.

Population structure, season, and food density may be factors that influence home range size in Meadow Voles (Getz 1961; Jones 1990). However, Meadow Voles showed no difference in spatial distribution or frequency of capture among blocks, plot types, vegetation types, or transplanting densities (Table 3). The lack of association with the presence of the *Miscanthus* cultivars is somewhat surprising, given that rhizomes

were still present belowground and roots are an important winter food source for Meadow Voles (Lindroth and Batzli 1984). Trapping immediately after transplanting, when *Miscanthus* and Switchgrass densities were highest, might have improved the likelihood of detecting a distinct pattern of Meadow Vole distribution. The lack of a block effect indicates that capture numbers were similar across the whole study area. The observed uniform distribution of Meadow Voles during our trapping period may be a result of the decreased territorial behaviours that occur after the breeding season (McShea 1989, 1990).

In our experiment, stems of *M. × giganteus* were severed, but tops did not appear to have been consumed. However, some smaller shoots and the regrowth from cut shoots were consumed, so it is possible that the older plants were unpalatable to the herbivore.

Meadow Voles often show selective preferences for certain plant species in contrast to plant abundances within a habitat (Bergeron and Juillet 1979; Lindroth and Batzli 1984). Selective preferences have been related to plant tissue chemical content, specifically to low total phenolics (Bergeron and Jodoin 1987), but with little consistency in relation to concentrations of other compounds such as water, nitrogen, and alkaloids (Bélanger and Bergeron 1987; Marquis and Batzli 1989). Cafeteria-style feeding trials and plant tissue analyses would be necessary to determine whether Meadow Voles prefer *Miscanthus* and Switchgrass to other old-field species and whether this is related to nutritional content.

We do not know why the herbivore seemed to prefer the transplanted species, but this has also been observed previously. For example, Parker et al. (2010) recorded 71% mortality of transplanted Common Evening Primrose caused by Meadow Voles in an old field near Ithaca, New York. Similarly, Barney et al. (2012) noted minor mortality due to herbivory of *Miscanthus* and Switchgrass transplants in a field experiment in California, but did not attempt to identify the herbivore. In all cases, the plants affected were not naturally present in the habitat.

One hypothesis is that transplants of non-native plants that have been raised in a greenhouse or other protected environment may have lower levels of phenolics and other photo-protective chemicals and better nitrogen availability, and thus may be more palatable than those that have been grown in the field (Close and McArthur 2002). If this is the case, breeding programs that aim to reduce levels of lignins and other phenolics in certain plants to improve their use as biomass or forage (e.g., Sarath et al. 2007) could also make them more palatable to unwanted herbivores. Plant tissue analyses could be used to compare levels of photo-protective compounds in field- and greenhouse-grown plants as a first step in evaluating this hypothesis, followed by palatability tests with selected herbivores.

Selective herbivory by Meadow Voles and other vertebrate herbivores can dramatically reduce both plant diversity and the abundance of specific plant species (Howe and Brown 1999; Howe et al. 2002; MacDougall and Wilson 2007; Parker et al. 2010). Howe et al. (2002) compared experimental plantings of 18 prairie species in plots with and without Meadow Voles, and effects similar to our findings were evident only when the densities of Meadow Voles were >155 individuals/ha. This is a much lower density than our early winter population density estimate of 265 individuals/ha.

Selective herbivory of *M. × giganteus* and Switchgrass seedlings could be a factor affecting their establishment in planted fields and their invasion into novel habitats. Fields planted with these crops tend to have diverse assemblages of weedy species in the initial establishment years, and poor crop establishment could be related to competition from weeds as well as apparent competition mediated by vertebrate herbivory, particularly in years of high herbivore population density. More importantly, however, the escape and spread of these grasses into novel habitats could be mediated by vertebrate herbivory. Experiments will be required to assess the risk of invasion in habitats both with and without vertebrate herbivores such as Meadow Voles, and in years of high and low herbivore population density, to obtain a balanced assessment.

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Prescribed Burning Has Limited Long-Term Effectiveness in Controlling Trembling Aspen (*Populus tremuloides*) Encroachment into Fescue Grassland in Prince Albert National Park

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Encroachment into grassland by woody species is a global ecological phenomenon, and it is of particular concern in remnant fescue (*Festuca*) prairie at the aspen parkland boreal forest ecotone. Fire suppression is thought to encourage encroachment; however, prescribed burning as a means of controlling encroachment and restoring system structure, function, and composition has had variable success. The objective of this study was to determine the effects of different season of burn, number of annual burns, and number of years after burning treatments on Trembling Aspen (*Populus tremuloides*) encroachment into the fescue grasslands within Prince Albert National Park, Saskatchewan. Temporal changes in density and cover of Trembling Aspen in grassland and grassland-forest transition plant communities were evaluated using data from a prescribed burn study conducted in Prince Albert National Park from 1975 to 2010. The effect of year (indicating varying amounts of time relative to prescribed burning) and the interaction between spring burning and year reflect a stimulatory effect of burning on Trembling Aspen suckering. Increased Trembling Aspen cover in the forest transition community with more annual burns, burning in the fall, and the interaction between year and number of annual burns and increased Trembling Aspen cover in the grassland community with year indicate that none of the treatments had lasting control of Trembling Aspen encroachment. Ongoing Trembling Aspen encroachment despite prescribed burning may be due to important missing interactions between fire and grazing. A change in the use and expectation of prescribed burning is needed when attempting to suppress Trembling Aspen encroachment into the fescue grasslands.

Key Words: encroachment, fescue prairie, fire suppression, grassland, Trembling Aspen, *Populus tremuloides*, prescribed burning, succession, Prince Albert National Park of Canada, Saskatchewan.

Encroachment of woody species is a significant ecological management issue on a global scale, particularly in moist grasslands such as the Northern Great Plains (Moss and Campbell 1947; Maini 1960; Bailey and Wroe 1974). Species such as Trembling Aspen (*Populus tremuloides*) can threaten habitat and biodiversity through a reduction in grassland area, isolation and fragmentation of patches, and reduced connectivity and genetic flow between patches (Fu et al. 2008).

As a result of agriculture and urbanization, only 6% of the historical extent of the fescue (*Festuca*) prairie remains in Saskatchewan, Canada, and much of that is small remnant patches less than 65 ha in size (Gerry and Andersen 2002*). In addition to the loss of area, the natural historical fire regimes that are thought to have controlled encroachment by woody species into grassland have been altered. In the fescue grasslands found in Prince Albert National Park of Canada, the historical 15–40 year fire return interval is now greatly exceeded due to factors that include fire suppression and the low probability of large-scale fires in what is now a largely agricultural landscape (Weir 1996). Although the fescue grasslands in Prince Albert National Park constitute only a fraction of the remaining fescue prairie in Saskatchewan, they are of particular conservation interest, and effective strategies to control

encroachment into these and other grasslands is urgently needed (Gerry and Andersen 2002*; Fu et al. 2008; Parks Canada 2012*).

Encroachment by woody species into grasslands is controlled by interactions between climate, fire, and herbivory (Bailey and Wroe 1974; Campbell et al. 1994; Bork et al. 1997; Ripley and Archibold 1999; Hogg et al. 2008; Michaelian et al. 2010). Although prescribed burning is widely used to address encroachment and to restore grasslands by mimicking natural disturbance, effectiveness in suppressing Trembling Aspen varies with the treatments used and the site conditions (Pylypec and Romo 2003; Romo 2003).

It is important to determine how encroachment in a given area is affected by prescribed burn treatments, such as the number and the season of burns, to better focus efforts to control encroachment by woody species. An investigation of the long-term effectiveness of prescribed burning is also needed to determine whether, and for how long, encroachment is suppressed.

To determine the effectiveness of number of annual burns and season of burning in controlling encroachment by Trembling Aspen over time, we examined tree density and cover in the fescue grasslands of Prince Albert National Park. We examined the effects of three, four, and five annual burns within an eight-year period,

and we examined the effects of burning in the spring and fall. We used a 36-year dataset allowing comparisons of 1975 pre-burn, 1983 post-burn, 1995 burn recovery, and 2010 burn recovery to assess how the density and cover of Trembling Aspen changed over time with different prescribed burn treatments.

Increases in Trembling Aspen cover over time indicate that none of the prescribed burn treatments implemented in this study suppressed Trembling Aspen encroachment over the long term.

Methods

Study area

The study area is located in the southwestern portion of Prince Albert National Park (53°36'N, 106°31'W), approximately 50 km northwest of Prince Albert, Saskatchewan. The study area lies within the Boreal Transition Ecoregion, but patches characteristic of the more southern Aspen Parkland Ecoregion are common (Acton et al. 1998; Parks Canada 2012*). The Aspen Parkland Ecoregion is characterized by forest dominated by Trembling Aspen interspersed with patches of fescue grassland.

Three areas of fescue grassland in Prince Albert National Park were utilized during this study: Wastrom's Flats, Sugar Creek, and Rabbit Creek. The grassland in these areas is dominated by Plains Rough Fescue (*Festuca hallii*) and Slender Wheatgrass (*Elymus trachycaulus* ssp. *subsecundus*), while forest transition areas surrounding the grassland and in isolated pockets within the grasslands are dominated by Trembling Aspen.

An average of 452 mm of precipitation falls on the site annually, 329 mm as rainfall and 123 mm as snowfall (Environment Canada 2011*). Soils are Orthic Black Chernozems occurring on coarse to moderately coarse textured glaciofluvial deposits (Padbury et al. 1978*). Current disturbances in the study area include intermittent grazing by Plains Bison (*Bison bison bison*) and North American Elk (*Cervus elaphus*) and occasional recreational use by park visitors. Other anthropogenic influences include a vehicle trail and ploughed firebreaks that bisect the sites.

Study design and data collection

We examined the effect of prescribed annual burning on Trembling Aspen density and cover in open grassland and grassland-forest transition (forest transition) communities using a 36-year (1975–2010) dataset collected from permanently marked plots (Gunn et al. 1976*; Trottier 1985; Kenkel 2002*). All data used in this study are archived in the appendices to Guedo (2012).

The site was initially surveyed in 1975, approximately 28 years after the previous known fire. Burn treatments included season of burn (spring or fall) and number of annual burns (three, four, or five) that were applied between 1976 and 1982 in an incomplete factorial design (only the four-burn treatment was con-

ducted in the spring) (Table 1). Observational descriptions of the treatment areas and prescribed burns are provided in Gunn et al. (1976*) and Trottier (1985). Follow-up data were collected from surveys in 1983, 1995, and 2010. The resulting dataset captures Trembling Aspen density and cover prior to burning in 1975, in 1983 after all burning treatments were carried out, in 1995 after a moderate length of recovery after burning, and in 2010 after a longer length of recovery after burning.

Prescribed burns separate from the current study were conducted on the Sugar Creek site in 2006 and 2009. As density and cover data collected from the 2010 Sugar Creek survey would not reflect the original study design, the 2010 Sugar Creek data were excluded from the analysis.

Sampling was conducted in 20 plots—11 in the forest transition community and 9 in the grassland community (Table 1). The forest transition and grassland plant communities were subjectively defined by field observation at the beginning of the study in 1975. The forest transition plant community was defined as locations where Trembling Aspen encroachment was evident, given Trembling Aspen recruitment along the grassland-forest ecotone. The grassland community was defined by open areas free of Trembling Aspen encroachment. Each plot contained 25 permanent quadrats marked by a metal stake laid out in a square grid (Guedo and Lamb 2013).

For plots within the forest transition community, a 2-m² quadrat was used to collect density data by enumerating stems of Trembling Aspen.

In both the forest transition and grassland community plots, a 1-m² quadrat was used to collect canopy cover data for Trembling Aspen (Guedo 2012). Cover classes of Trembling Aspen (1 = 1–10%, 2 = 11–20% ... 10 = 91–100%) were recorded in the 1-m² quadrats in 1975, 1983, and 1995. Percentage cover data were recorded in 2010 and converted to cover class, for uniform treatment of data from all survey years.

Mid-point averages of each cover class (1 = 5%, 2 = 15% ... 10 = 95%) were calculated, and mean species cover for each plot was used in the cover analysis. Similarly, mean stem density in each plot was used in the density analysis. As plots were specifically set up to monitor change in Trembling Aspen cover and density over time under different prescribed burning treatments, plots were the experimental unit in this study.

Statistical analysis

The effects of the number of burns, season of burning, and time since burning on Trembling Aspen density were determined using generalized linear mixed models fitted with a Poisson distribution. This approach was taken, as a Poisson distribution is most appropriate for count data (this study assessed number of Trembling Aspen stems under the different burn treatments) (Crawley 2007).

TABLE 1. Prescribed burn treatment combinations used in the Prince Albert National Park of Canada prescribed burn study, 1975–2010. Grassland areas include Wasstrom’s Flats, Rabbit Creek, and Sugar Creek. Plots were set out in grassland and forest transition plant communities (grassland–Trembling Aspen forest ecotone where Trembling Aspen encroachment was evident in 1975). Plot numbers identify treatment replications within each community type and indicate the number of plots subjected to different treatment combinations applied between 1975 and 1982: season of burning (fall or spring) and number of annual burns (three, four or five). No grassland plots were established in the Rabbit Creek grassland.

No. of grassland plots	No. of forest transition plots	Season of prescribed burning	No. of prescribed annual burns	Year of prescribed burning
Wasstrom’s Flats				
2	2	Fall	3	1975, 1979, 1980
2	2	Fall	5	1975, 1976, 1979, 1980, 1981
4	4	Spring	4	1976, 1977, 1981, 1982
Rabbit Creek				
0	1	Fall	4	1975, 1976, 1980, 1981
0	1	Spring	4	1976, 1977, 1981, 1982
Sugar Creek				
1	1	Fall	4	1975, 1976, 1980, 1981
1	1	Spring	4	1976, 1977, 1981, 1982

The effects of the burn treatments on Trembling Aspen cover were analyzed using general linear models, as the cover class data used in the analysis were the mean quadrat cover in each plot, and were thus presumed to follow a normal distribution. A mixed model approach was used to address the non-independence of samples arising through repeated surveys of plots and the nesting of plots within the different grassland areas.

All analyses were conducted using linear mixed-effects models (lmer and lme functions) in the R.2.12.1 package (R Development Core Team 2011).

Model selection procedures (Crawley 2007) were used where a maximal model containing all possible treatments and treatment combinations was reduced by grouping non-significantly different treatments and removing non-significant model terms (Crawley 2007). If a new model with combined treatments or removed terms resulted in a non-significant drop in Akaike’s Information Criterion (AIC) and in variance explained ($P \geq 0.05$) from the previous model, it was retained and further simplified if possible. The minimally adequate (best) model was then compared to a null model containing only the random terms.

A significant difference between the null and minimally adequate (best) model ($P < 0.05$) confirmed that the fixed factors including burn treatment combinations retained in the minimally adequate (best) model represented significant differences in Trembling Aspen density or cover. Using this model selection approach is particularly powerful in studies with complex experimental design and relatively small sample sizes, as combining and removing non-significant treatment effects permits a more powerful test of the remaining model terms (Crawley 2007).

Three separate models were generated: one for Trembling Aspen density in the forest transition community, one for Trembling Aspen cover in the forest transition

community, and one for Trembling Aspen cover in the grassland community. A model for Trembling Aspen density in the grassland community was not possible, as the initial study design did not collect data on the density of woody species in the grassland plots, presumably because the presence of Trembling Aspen in the grassland was negligible when the plots were established. The maximal models for Trembling Aspen density and Trembling Aspen cover in the forest transition community included year, season, and number of annual burns as main effects, and the interactions between year and season and between year and the number of annual burns.

No grassland plots were established in the Rabbit Creek site due to its small size, providing only a single replicate of the four annual burns in the fall treatment combination in the grassland community. Having only one replicate of this treatment combination in the grassland community would likely cause spurious results for that treatment interaction; thus the maximal model for the grassland plant community included only the year, season, and number of annual burns. As spring treatment plots were burned only four times, the incomplete factorial design precluded testing the interaction between the season and number of annual burns in all models.

In all models, the year main effect is simply change in Trembling Aspen density or cover over time, shown through the year in which sampling occurred: in 1975 prior to burning, or in 1983, 1995, or 2010 with varying amounts of time after the prescribed burn treatments were applied between 1975 and 1982. The interaction between year and season indicates how Trembling Aspen cover or density changed over time with burning in either fall or spring, and the interaction between year and number of annual burns indicates how Trembling Aspen cover or density changed over time with either three, four, or five annual burns being used.

Random factors for all analyses included plot and grassland area, with plots nested within grassland areas. Random factors were specified to address the non-independence of samples arising through repeated measures of plots and the nesting of plots within the different grassland areas.

Results

Trembling Aspen density in the forest transition community was significantly affected by year and the year–season interaction but was not affected by the number of annual burns (Figure 1). The best Trembling Aspen density model included year with 1975 and 1995 combined, season, and the year–season interaction (maximal vs. best model $\chi^2_8 = 13.18$, $P = 0.214$). Trembling Aspen density was significantly lower in 2010 (0.8 m^{-2}) than in 1983 (3.3 m^{-2} , $z = -3.84$, $P < 0.001$). There was a year–season interaction, as density in plots burned in spring was 1.5 m^{-2} in 1975–1995 and 4.3 m^{-2} in 1983, while the density in plots burned in fall was 2.0 m^{-2} and 2.4 m^{-2} over the same period ($z = -3.98$, $P < 0.001$).

Cover of Trembling Aspen in the forest transition community was significantly affected by number of annual burns, season, and the interaction between year and the number of annual burns (Figure 1). The best model for Trembling Aspen cover in the forest transition community included year (1975, 1983, and 1995 combined), season, number of annual burns, the year–number of annual burns interaction, and the year–season of burn interaction (maximal model vs. best model $F_{11,19} = 12.75$, $P = 0.121$). The year–season interaction was not statistically significant; however, it was retained in the model, as its removal reduced the variance explained between models (previous minimally adequate model vs. model with year–season interaction removed $F_{10,11} = 3.66$, $P = 0.056$).

Trembling Aspen cover in the forest transition community was greater with four annual burns ($11.4\% \text{ m}^{-2}$, $t = 5.21$, $P = 0.002$) and five annual burns ($13.7\% \text{ m}^{-2}$, $t = 2.48$, $P = 0.048$) than with three annual burns ($9.4\% \text{ m}^{-2}$). Plots with spring burns had less Trembling Aspen cover ($10.7\% \text{ m}^{-2}$) than plots with fall burns ($12.1\% \text{ m}^{-2}$, $t = -2.51$, $P = 0.046$). Cover increased through time with burns, as shown by the year–number of annual burns interaction: a) plots with four annual burns had $4.9\% \text{ m}^{-2}$ Trembling Aspen cover in 1975, 1983, and 1995 and $37\% \text{ m}^{-2}$ in 2010 ($t = -4.94$, $P < 0.001$), and b) plots with five annual burns had $8.8\% \text{ m}^{-2}$ Trembling Aspen cover in 1975, 1983, and 1995 and $28.4\% \text{ m}^{-2}$ in 2010 ($t = -2.08$, $P = 0.046$). The year–season interaction shows plots burned in the fall had $8.0\% \text{ m}^{-2}$ Trembling Aspen cover in 1975, 1983, and 1995 and $27.0\% \text{ m}^{-2}$ in 2010, while plots burned in the spring had $4.0\% \text{ m}^{-2}$ Trembling Aspen cover in 1975, 1983, and 1995 and $34.7\% \text{ m}^{-2}$ Trembling Aspen cover in 2010 ($t = 1.83$, $P = 0.077$).

Cover of Trembling Aspen in the grassland community was significantly affected by year, but not by season or the number of annual burns (Figure 1). The best model for Trembling Aspen cover in the grassland community included year (1975, 1983, and 1995 combined) (maximal model vs. best model $F_{5,10} = 2.58$, $P = 0.764$). Trembling Aspen cover in the grassland increased significantly between 1975, 1983, and 1995 ($1.5\% \text{ m}^{-2}$) and 2010 ($4.0\% \text{ m}^{-2}$, $t = -4.45$, $P < 0.001$).

Discussion

Managing woody species encroachment is critical in maintaining grassland; this study demonstrates that relying on a short series of prescribed fires alone can be ineffective. This response is not entirely unexpected, as the use of prescribed burning as a means of controlling encroachment has had negligible results in other grasslands in the Northern Great Plains (Heisler et al. 2003; Heisler et al. 2004; Briggs et al. 2005) and the burning treatments used at this site had limited effects on the frequency and abundance of forest understory species (Guedo and Lamb 2013). Infrequent fire in other areas of the fescue prairie can also lead to increased encroachment by Trembling Aspen, Bog Birch (*Betula pumila*), and willow (*Salix*) species (Bailey et al. 1990; Bork et al. 1997; Bork and Burkinshaw 2009).

The failure of a short series of prescribed burns to suppress encroachment over the long term may be explained by the stimulatory effect fire can have on Trembling Aspen. Control of regrowth after burning requires a secondary form of suppression. If suckering is left unchecked, Trembling Aspen can colonize and dominate disturbed sites (Maini 1960; Schier 1973; Mueggler 1989; Keyser et al. 2005). Increased soil water content and temperature after fire are considered important factors in sucker initiation, facilitating growth earlier in the spring and providing a longer growing season. Increased soil water content and temperature are also thought to promote auxin degradation and cytokinin synthesis (Johnston 1981; Hungerford 1988*; Fraser et al. 2002). The increased density observed in 1983 in Prince Albert National Park with spring burning agrees with these findings, as soil temperatures likely increased earlier in the season with spring burning than with fall burning.

Cover of Trembling Aspen may also increase with time after burning as a result of the growth of suckers and the recovery of mature trees in the overstory. With this increase in growth, however, low light intensities may negatively affect growth of individual Trembling Aspen suckers (Farmer 1963). Inter- and intraspecific competition for light and other resources promotes self-thinning, as evidenced here by a reduction in density coinciding with an increase in overall cover of Trembling Aspen over time following burning.

Self-thinning of new stems may be accelerated with spring burning, as we found that density was initially

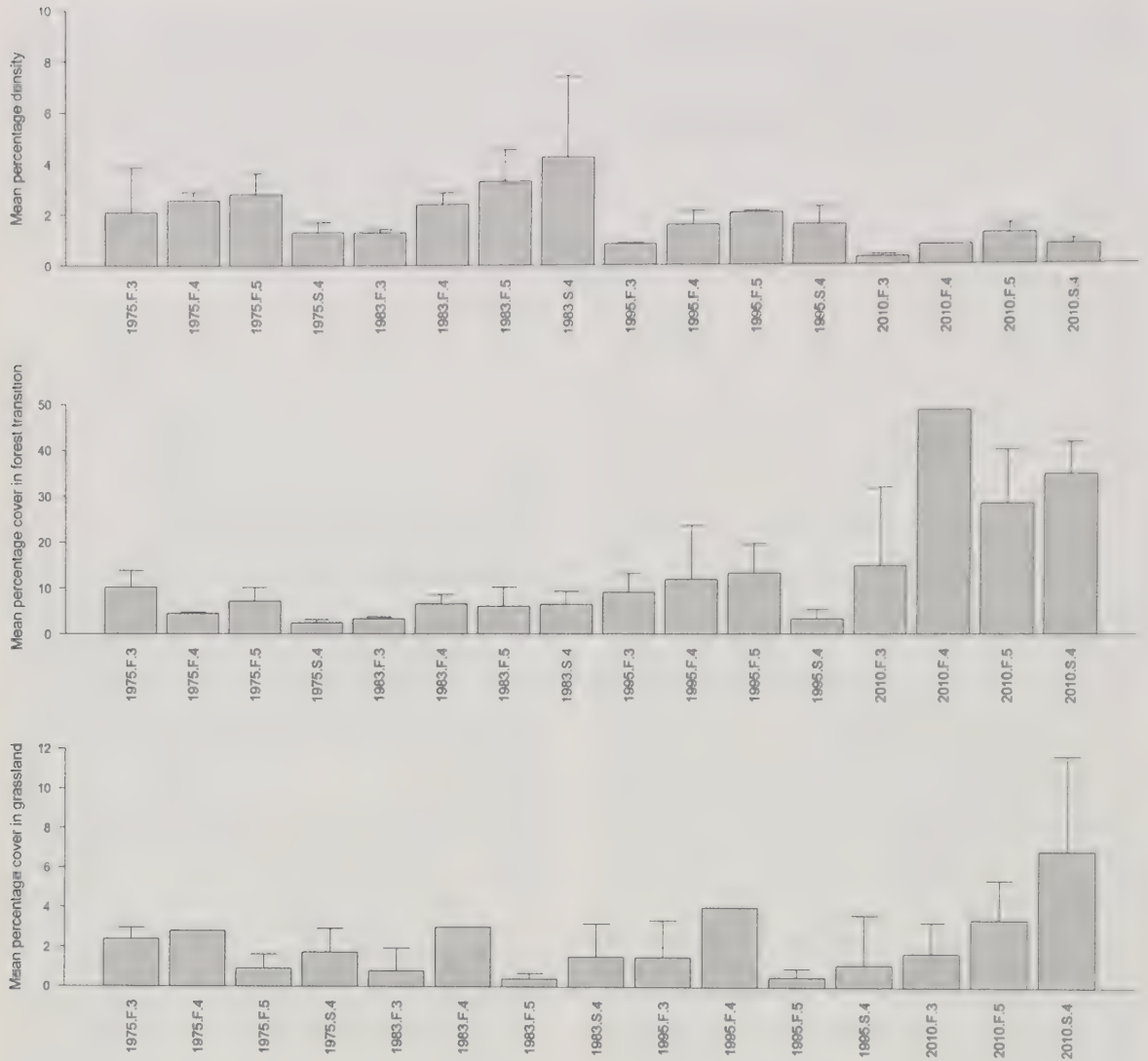


FIGURE 1. Mean Trembling Aspen (*Populus tremuloides*) density (stems m^{-2}) in the forest transition community, mean Trembling Aspen percentage cover in the forest transition community, and mean Trembling Aspen percentage cover in the grassland community with the prescribed burn treatments applied during the prescribed burn study in Prince Albert National Park of Canada, 1975–2010. Treatments codes on the x axis indicate year of sampling (1975, 1983, 1995, and 2010), season of burning (F = fall, S = spring), and number of annual burns (three, four, and five). Error bars are one standard deviation. The four fall burn treatments had only one replicate in 2010 for density and cover in the forest transition, and thus do not have error bars. The four fall burn treatments had only one replicate in 1975, 1983, and 1995 for cover in the grassland, and thus do not have error bars. There was no treatment with four fall burns in the grassland in 2010. Due to the complexity of the interactions in the models, letters indicating significance of fixed effects are not shown.

higher in plots that were burned in the spring, where competition for light and resources would subsequently be more intense (Hendrickson 1988). Increased competition in plots burned in the spring as a result of greater sucker density may also explain why less cover was observed over time in plots burned in the spring than in plots burned in the fall in the forest transition community.

Trembling Aspen recovery depends on stored resources after disturbance, and frequency of disturbance

is important in determining suckering at the community level (Bellingham and Sparrow 2000). If Trembling Aspen recovered between burn events, suckering might have been stimulated more frequently on plots burned four and five times than on plots burned three times. This increase in suckering may explain why cover was greater with four and five annual burns in the forest transition community. With no initial Trembling Aspen overstory in the grassland community, post-burn Trembling Aspen growth was likely less limited by lack of

light, and this may explain the increase in Trembling Aspen cover over time in this community (Huffman et al. 1999).

Application of three to five prescribed fires alone over a period of three to seven years has clearly not been effective in controlling Trembling Aspen encroachment into the fescue grasslands of Prince Albert National Park. In addition, increases in Trembling Aspen cover occurred despite using prescribed burn treatments set within the historical fire return interval. Controlling Trembling Aspen encroachment is much more complex than using fire on Trembling Aspen alone, and it likely involves successional pathways, including interactions of climate, fire, grazing, and possibly behavioural interactions between grazers and predators (Knapp and Seastedt 1986; Campbell et al. 1994; Hogg et al. 2008; Fuhlendorf et al. 2009; Michaelian et al. 2010; Seager et al., *in press*).

In the fescue grasslands of Prince Albert National Park, integrated management practices such as increased fire frequency and grazing after burning are likely needed to address suckering and to prevent recovery of Trembling Aspen after fire (Bailey et al. 1990; Bork et al. 1996; Heisler et al. 2004; Bork and Burkinshaw 2009). Opportunities exist in Prince Albert National Park to mimic natural disturbance regimes, such as interactions of fire and grazing. Relying on prescribed burning alone using treatments such as those included in this study is not likely to be effective in controlling Trembling Aspen.

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Notes

Consumption of Truffles and other Fungi by the American Red Squirrel (*Tamiasciurus hudsonicus*) and the Eastern Chipmunk (*Tamias striatus*) (Sciuridae) in Northwestern Ontario

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Teron, Jocelin N., and Leonard J. Hutchison. 2013. Consumption of truffles and other fungi by the American Red Squirrel (*Tamiasciurus hudsonicus*) and the Eastern Chipmunk (*Tamias striatus*) (Sciuridae) in northwestern Ontario. *Canadian Field-Naturalist* 127(1): 57–59.

Faecal matter collected from the American Red Squirrel (*Tamiasciurus hudsonicus*) and the Eastern Chipmunk (*Tamias striatus*) on the campus of Lakehead University in Thunder Bay, Ontario, was examined for the presence of consumed fungal tissue. A total of 14 faecal samples were collected from live-trapped animals over six trapping periods (19 June to 25 September 2010). Eight samples contained intact remains of spores representative of hypogeous truffle fungi found in the genera *Elaphomyces*, *Gautieria*, *Hymenogaster*, *Hysterangium*, and *Leucangium*, as well as spores of epigeous mushrooms found in the orders Boletales and Pezizales and possibly in the family Tricholomataceae of the Agaricales. The results of this brief survey suggest not only the importance of mycophagy in the diet of American Red Squirrels and Eastern Chipmunks in the boreal mixed wood forests of northwestern Ontario but also the important role played by sciurids in vectoring spores of truffle fungi in this region.

Key Words: hypogeous fungi, *Tamiasciurus hudsonicus*, *Tamias striatus*, Sciuridae, mycophagy, truffles, *Elaphomyces*, *Gautieria*, *Hymenogaster*, *Hysterangium*, *Leucangium*, Boletales, Pezizales, Tricholomataceae, Agaricales, Ontario.

Mycophagy, or the consumption of fungi, is a worldwide phenomenon found among small to large mammals, including humans (Maser et al. 2008). Members of the family Sciuridae (mainly tree squirrels and chipmunks) are the most frequently observed mammalian mycophagists (Fogel and Trappe 1978). The availability and variety of fungi, including truffles, in forest ecosystems when in season and the minimal foraging efforts needed to locate them are what make fungal fruiting bodies a common and valuable food source to sciurids (Cork and Kenagy 1989; Maser et al. 2008). The American Red Squirrel (*Tamiasciurus hudsonicus* Erxleben) alone has been documented eating 89 species of fungi (Fogel and Trappe 1978), and it is well known that the American Red Squirrel, along with other tree squirrels, dries fungi in tree branches or in the sun before storing them elsewhere (Fogel and Trappe 1978; Lurz and South 1998; Vernes and Poirier 2007; Maser et al. 2008). Many sciurids are known to cache fungi over the winter making fungal fruiting bodies a significant component of a sciurid's diet year round (Maser et al. 1985; Currah et al. 2000; Vernes et al. 2004).

When sciurids dig up and ingest fruiting bodies of hypogeous (fruiting underground) truffle fungi, they also act as vectors for spores, since the spores are indigestible and are excreted intact in faeces (Johnson 1996; Maser et al. 1978). Another means of spore dispersal occurs when fruiting bodies are dug up by sciurids and

broken open, releasing spores into the air and onto the fur and paws of the animal (Johnson 1996). For this reason, truffle fungi are dependent on sciurids and other foragers for spore dispersal (Fogel and Trappe 1978; Johnson 1996; Maser et al. 2008). It has been suggested that co-evolution has occurred between hypogeous truffle fungi and their vectors (Maser et al. 2008).

Studies on mycophagy by sciurids in Canada are limited and have included the work of Anderson (2003) in coastal British Columbia, Sidlar (2012) in central British Columbia, Currah et al. (2000) in northeastern Alberta, Vernes et al. (2004) in New Brunswick, and observations by Buller (1922) in Manitoba and adjacent northwestern Ontario. As American Red Squirrels were observed digging up truffle fungi on the Lakehead University campus, we decided to investigate fruiting body consumption and the diversity of fungal species eaten, based on spores found in sciurid faeces.

Study Area and Methods

Live-trapping of sciurids occurred every two to three weeks from 19 June to 25 September 2010, for a total of six sampling periods. No specific species were targeted, but we focused on diurnal species. Three transects were set up, each containing four Sherman live traps. Each transect was approximately 100 metres in length, with each trap in the transect approximately 30 metres apart. Peanut butter on a piece of plain cracker

was provided as a food source. When trapping occurred during dry and/or hot conditions, a slice of apple was used instead to supply water.

Traps were always set before sunrise, and were checked approximately four and a half hours later. If any animals were captured, identifications were made before release.

Trapping occurred in natural forested areas of the Lakehead University campus in Thunder Bay, Ontario, in proximity to the McIntyre River. The forest cover in these areas is conifer dominant mixed woods composed mainly of White Spruce (*Picea glauca* (Moench) Voss), Balsam Fir (*Abies balsamea* (L.) Mill.), Jack Pine (*Pinus banksiana* Lamb.), and Trembling Aspen (*Populus tremuloides* Michx.). The forest cover is characteristic of the transition zone between the boreal forest region (B.9 Superior) (Rowe 1972) and the Great Lakes St. Lawrence Forest Region (L.11 Quetico) (Rowe 1972).

Protective gloves and a surgical mask were worn during handling of any traps containing captured animals and faecal matter. Faecal material collected from the traps was transported from the field in small plastic bags and frozen as soon as possible. Each of the faecal samples was assigned a unique three-digit code indicating the trapping date, the trap line, and the trap number.

Samples were dried in aluminum weighing boats at 100°C for 48 hours. They were then weighed, ground up with a mortar and pestle, and added to 70% ethanol (ethyl alcohol) at a ratio of 0.01g dry weight to 0.2 mL ethanol. From these samples, spore counts were completed using a hemacytometer. Faecal material was mounted in Melzer's reagent (Castellano et al. 1989) and examined using a Nikon Eclipse E400 phase contrast light compound microscope. Spore morphology

was used for identification at the genus (or family) level utilizing key taxonomic manuals (e.g., Castellano et al. 1989; Trappe et al. 2007).

Results and Discussion

Only two sciurid species were trapped over the entire trapping period: the American Red Squirrel (4 faecal samples) and the Eastern Chipmunk (10 faecal samples). As no animals were enumerated, it was possible that some of the faecal samples were from repeat captures. Other sciurids occur in forested areas in and around Thunder Bay. These species include the Northern Flying Squirrel (*Glaucomys sabrinus* Shaw), which is a nocturnal species (Banfield 1974); the Least Chipmunk (*Tamias minimus* Bachman); and the Eastern Gray Squirrel (*Sciurus carolinensis* Gmelin), which appears to be more restricted to urban settings. Of the samples collected, all of those from American Red Squirrels contained fungal spores; however, only 4 out of the 10 Eastern Chipmunk samples contained fungal spores.

Of the faecal samples that contained spores, total spore concentrations ranged from 75 million spores per gram of faecal sample dry weight (sample 1-2-2) to 332.5 million spores per gram of faecal sample dry weight (sample 1-1-2). Recognizable taxa varied considerably in concentration per faecal sample (Table 1).

Eight distinctive spore types were identified (Table 1). Of these, five clearly belonged to genera of hypogeous truffle fungi: *Elaphomyces*, *Gautieria*, *Hymenogaster*, *Hysterangium* and *Leucangium* (known formerly as *Picoa*). These fungi have been reported in the literature from studies done elsewhere in North America and Europe (Maser and Maser 1988; Currah et al. 2000; Bertolino et al. 2004; Vernes et al. 2004).

TABLE 1. Taxa of fungi and their spore concentrations found in faecal pellets collected from live-trapped sciurids in Thunder Bay, Ontario, between 19 June and 25 September 2010.

Sample no.	Date faeces collected	Sciurid species	Spore types found	Spores/g dry weight collected (millions)
1-1-2	19 June 2010	Eastern Chipmunk	unknown	325.0
			<i>Leucangium</i> sp.	5.0
1-2-1	19 June 2010	American Red Squirrel	<i>Hymenogaster</i> sp.	2.5
			<i>Hysterangium</i> sp.	162.5
			Tricholomataceae	60.0
			<i>Hymenogaster</i> sp.	17.5
1-2-2	19 June 2010	Eastern Chipmunk	<i>Elaphomyces</i> sp.	7.5
			<i>Hysterangium</i> sp.	60.0
1-3-2	19 June 2010	American Red Squirrel	<i>Leucangium</i> sp.	15.0
			<i>Hysterangium</i> sp.	115.0
			Pezizales	7.5
			<i>Gautieria</i> sp.	5.0
3-3-4	31 July 2010	American Red Squirrel	<i>Elaphomyces</i> sp.	2.5
4-1-2	14 August 2010	American Red Squirrel	Boletales	147.5
4-2-3	14 August 2010	Eastern Chipmunk	unknown	147.5
			Boletales	197.5
6-2-4	25 September 2010	Eastern Chipmunk	Boletales	15.0
			unknown	92.5

Three remaining recognizable spore types encountered included those representative of the basidiomycete order Boletales. However, it was difficult to determine whether the spores belonged to an epigeous (fruiting above ground) mushroom genus (e.g., *Suillus*) or to a hypogeous truffle genus (e.g., *Rhizopogon*) within this order, as spore morphology is similar in both groups. The spores belonging to a representative of the ascomycete order Pezizales were larger and more conspicuous than other spores in the faecal samples, but they could not be identified to the genus level. Spores similar to those produced by some members of the epigeous mushroom family Tricholomataceae were also found. However, there were several spore types encountered that could not be identified and were labelled as unknown (Table 1).

The results of this brief survey suggest not only the importance of mycophagy in the diet of American Red Squirrels and Eastern Chipmunks in the boreal mixed wood forests of northwestern Ontario but also the important role played by sciurids in vectoring spores of truffle fungi in this region. Further studies with other sciurid species are required, in addition to the need for testing of spore viability after passage through the digestive tract.

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First Record of the Bee *Melitta americana* (Smith) (Hymenoptera: Melittidae) for Quebec and Canada

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Payette, André. 2013. First record of the bee *Melitta americana* (Smith) (Hymenoptera: Melittidae) for Quebec and Canada. Canadian Field-Naturalist 127(1): 60–63.

The first record of the bee *Melitta americana* (Smith) (Hymenoptera: Melittidae) for the province of Quebec and for Canada is reported. Female bees were found foraging on pollen and nectar on flowers of the Large Cranberry, *Vaccinium macrocarpon* Aiton (Ericaceae), in a cultivated Large Cranberry field in the Centre-du-Québec region.

Première mention de l'abeille *Melitta americana* (Smith) (Hyménoptères : Mélittides) pour la province du Québec et pour le Canada. Les abeilles femelles ont été observées en train de butiner du pollen et du nectar sur les fleurs de canneberges à gros fruits, *Vaccinium macrocarpon* Aiton (Éricacées), dans une culture commerciale de canneberges dans la région du Centre-du-Québec.

Key Words: oligolectic bee, *Vaccinium macrocarpon*, Large Cranberry, cranberry bog, native pollinator, nesting site, pollen analysis, range extension, Quebec, Canada.

Mots-clés : abeille oligolecte, *Vaccinium macrocarpon*, canneberge à gros fruits, cannebergière, pollinisateur indigène, site de nidification, analyse pollinique, extension d'aire, Québec, Canada.

Cranberries are an important commercial crop in the United States and Canada, particularly in Quebec. Production in Quebec has increased rapidly in recent years, from three producers in 1992 with a total of 127 ha (318 acres) to 80 producers in 2012 with a total of 2861 ha in production (7071 acres) (Association des producteurs de canneberges du Québec 2012*). Quebec, the third largest cranberry producing region in the world (Jean-Pierre Deland, Club environnemental et technique Atocas Québec (CETAQ), personal communication), produced 84 million kg (186 million pounds) by volume of harvested of cranberries in 2012 (Association des producteurs de canneberges du Québec 2012*), valued at \$70 million. In 2011, 7754 Honey Bee (*Apis mellifera* L.) colonies were rented for the pollination of cranberries, for a total value of \$786,200 (Institut de la statistique du Québec 2012*). Understanding the diversity of native bees associated with large commercial cranberry operations in Quebec could have a significant economic impact on cranberry production.

Study Area and Methods

Bee biodiversity inventories were conducted in 12 commercial Large Cranberry (*Vaccinium macrocarpon*) (Ericaceae) fields in southern Quebec from 2005 to 2012. Two of the fields are on peat deposits and ten are on acidic sand. During the inventories, a particular emphasis was placed on the discovery of *Megachile addenda* Cresson (Megachilidae), a common species in commercial Large Cranberry crops in Massachusetts (Cane et al. 1996). The first survey of flower-visiting bees took place in the Outaouais region (western Quebec) from 25 to 29 June 2005, followed by Lanaudière region (on the north shore of the St. Lawrence River) in July 2006, and by the Centre-du-Québec region (on

the south shore of the St. Lawrence River midway between Montreal and Quebec City) from 11 to 15 July 2005, from 8 June to 20 July 2006, and in July 2009 and 2012. Other bee collecting took place, before, during, and after the flowering period of *V. macrocarpon*, on different species of plants in bloom around these sites. In the Centre-du-Québec, the Large Cranberries flowered in late June and early July. The flowering period lasted from three to four weeks, depending on the weather.

Many species of wild bees visited the Large Cranberries surveyed, mostly represented by bumble bees, *Bombus* spp. (Apidae), and *Megachile* spp. (Megachilidae, leaf-cutting bees), but few occurred in large numbers. In one of the peat bog farms (the Daveluyville site), the most frequent pollinator was the introduced Honey Bee, followed by the native solitary bee *Melitta americana* (Smith) (Payette 2013*).

In southeastern Massachusetts, MacKenzie and Averill (1995) have identified bumble bees and Cane et al. (1996) *Megachile addenda* as common pollinators of the Large Cranberry in this region. It is not a common species in Canada or in Quebec (Payette, *in press*), and I did not find *Megachile addenda* on Large Cranberry flowers or in the vicinity of the crops surveyed. On the Large Cranberry crops in Ontario, Kevan et al. (1983) did not find this species of Megachilidae.

After the first specimens of *Melitta americana* were found in Quebec, I consulted the following collections to verify whether a species of that genus had previously been found in Quebec or in other Canadian provinces (acronyms follow the Biodiversity Collections Index 2013*): author's collection, Montreal, Quebec; Marc Payette collection, Venise-en-Québec, Quebec; Canadian National Collection of Insects and Arachnids, and Nematodes, Agriculture and Agri-Food Canada.

Ottawa, Ontario (CNC); Insectarium de Montréal collection, Montreal, Quebec (IMQC); University of Kansas Natural History Museum, Division of Entomology, Snow Collections, Lawrence, Kansas (SEMC); Lyman Entomological Museum collection, McGill University, Macdonald Campus, Sainte-Anne-de-Bellevue, Quebec (LEMQ); Packer's Apoidea Collection, Department of Biology, York University, Toronto, Ontario (PCYU); Collection entomologique Ouellet-Robert, département de sciences biologiques de l'Université de Montréal, Montreal, Quebec (QMOR); and the University of Guelph Insect collection, School of Environmental Sciences, University of Guelph, Guelph, Ontario (DEBU).

No previous records were found.

Taxonomy

New phylogenetic hypotheses suggest that one of the smallest families, the Melittidae, could be the basal group of the bee clade (Danforth et al. 2006). Within this family, ground nesting bees of the genus *Macropis* and *Melitta* are Holarctic and are found in the eastern and central United States and southern Canada. *Macropis* bees are apparently all oligolectic (specialists), and the females collect pollen and floral oil on their host-plant, *Lysimachia* (Primulaceae) (Michez et al. 2008).

The bees of the genus *Melitta* Kirby, 1802 resemble species of *Andrena* (Andrenidae) in general aspects of body morphology. The facial foveae are absent, and they have one subantennal suture below each antenna. The labrum has a lateral apical lobe, a character not found in other bees. The genus is Holarctic and African in distribution (Michener 2007; Michez and Eardley 2007). Nesting behaviour of *Melitta* has been described by Türgari (1968), the biology by Celary (2006), the ecology by Michez and Eardley (2007), and the pollination ecology by Cane et al. (1985). *Melitta* appear to be oligolectic on different plant families (Michez et al. 2008).

In eastern North America, *Melitta* species appear to be restricted to a few species of Ericaceae (Snelling and Stage 1995; Michener 2007; Michez et al. 2008). Four described species in the genus are found in North America: one in Mexico and the western United States, and three in the eastern United States. *M. eickworti* is known from northern New York, whereas *M. americana* is generally found farther south (Massachusetts to Florida) (Bartholomew 2004).

Specimens were identified as *Melitta americana* (Smith) using the keys of Mitchell (1960) and Snelling and Stage (1995). Subsequently (in 2007 and 2009), voucher material was sent to Charles D. Michener (University of Kansas, Lawrence, Kansas) for verification and identification, and to Cory Sheffield (Royal Saskatchewan Museum, Regina, Saskatchewan) and Laurence Packer (York University, Toronto, Ontario). The latter authors will use the material collected in the pres-

ent study in an ongoing study to obtain DNA barcodes for all bees in Canada and for a generic key to bees in Canada. DNA barcode sequences will be available on the Barcodes of Life Data system.

For identification, users of the key in the Bee Genera of Eastern Canada (Packer et al. 2007) should insert the following couplet into couplet 19:

- Apex of marginal cell on costal margin of forewing or pointed and approximately one vein-width from costal margin
..... *Melitta americana* (Smith)
- Apex of marginal cell curved away from costal margin of forewing
..... [resume with couplet 19]

Results

Bees of the genus *Melitta* were found and observed at only one site in Daveluyville (46°14'55"N, 72°08'29"W), Quebec. The site is a small farm established in 1997 on peatlands extending to 16 beds of 1 ha each separated by dykes. This farm has a diverse set of natural habitats, with deciduous and coniferous forests adjacent to the Large Cranberry fields, which are located in an open area of sphagnum bogs and fens. The *Vaccinium* species surrounding the cultivated crops are Early Lowbush Blueberry (*V. angustifolium* Aiton), Highbush Blueberry (*V. corymbosum* L.), Velvet-leaved Blueberry (*V. myrtilloides* Michaux), and Small Cranberry (*V. oxycoccus* L.).

Specimens were found on 15 July 2005, 12 July 2006, 10 July 2009, and 6 July 2012; they were foraging exclusively on the flowers of the cultivated Large Cranberry. I collected more specimens from a nesting site I discovered in the dyke, between the edge of the crop and the bog, on 6 July 2012 at the same place. Following the discovery of the nesting site, a pollen analysis of *M. americana* provisioning masses from a total of three cells from three different nests was made. The results of this analysis confirmed that 100% of the pollen came from *V. macrocarpon*. At this site, *M. americana* uses a single floral host, *V. macrocarpon*, and it seems to be an oligolectic species for its pollen and nectar needs.

The presence of specimens at the collecting site during the summers of 2005, 2006, 2009, and 2012 and at the nesting site in 2012 indicates that the population is likely well established and the cultivated Large Cranberry field is a suitable habitat for the species. My observations so far support the information about the oligoleges of *M. americana* on various *Vaccinium* spp. (Ericaceae) in Snelling and Stage (1995) and Michez and Eardley (2007).

Specimens examined

Voucher specimens (34 males and 53 females) collected by net sweeping by A. Payette, Daveluyville, Quebec, 46°14'55"N, 72°08'29"W, and deposited in the following collections: collected on *V. macrocarpon* flowers: 1 female on 15 July 2005, 1 male and 2 fe-

males on 12 July 2006, 11 males and 7 females on 10 July 2009, 8 males and 25 females on 6 July 2012, 7 males and 3 females near the entrance of nesting site on 6 July 2012 (author's collection); 1 male and 2 females on 10 July 2009 (CMPA); 1 male and 2 females on 10 July 2009 (CNC); 1 male and 2 females on 10 July 2009 (IMCQ); 1 male and 3 females on 10 July 2009 (SEMC); 1 male and 2 females on 10 July 2009 (LEMQ); 1 male and 2 females on 10 July 2009 (PCYU); and 1 male and 2 females on 10 July 2009 (QMOR).

As no additional specimens were found in the collections cited above from Quebec or elsewhere in Canada, the specimens recorded here constitute a new record for Quebec and for Canada.

The collection in Daveluyville, Quebec, is the northernmost for the genus *Melitta* in North America (46°N) and it represents a range extension of about 550 km from Massachusetts.

Discussion

Cranberries need bees for pollination (McGregor 1976). *M. americana* is a specialized pollinator species and I observed that it is adapted to Quebec's climatic conditions. The population discovered in Daveluyville, aside from its conservation interest, should be studied more intensively to develop adapted management practices that would encourage the expansion and use of *M. americana* as a potential pollinator of Large Cranberry crops or could also be interesting for other *Vaccinium* spp. for Quebec producers.

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Encounter Competition between a Cougar, *Puma concolor*, and a Western Spotted Skunk, *Spilogale gracilis*

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Encounter competition occurs frequently over food resources and may include kleptoparasitism, where scavengers usurp prey killed by carnivores. Scavenging may have important adverse effects on carnivores and may result in higher than expected kill rates by predators. Using camera traps placed on a Black-tailed Deer (*Odocoileus hemionus columbianus*) carcass killed by a Cougar (*Puma concolor*) in California, we observed a series of encounters in which a Western Spotted Skunk (*Spilogale gracilis*) temporally usurped the carcass from the Cougar. The Western Spotted Skunk also successfully defended the carcass when the Cougar returned and attempted to feed. The Spotted Skunk was about 1% of the mass of the Cougar. Our observation is the largest reported size differential of a mammalian species engaging in successful encounter competition.

Key Words: Cougar, Mountain Lion, *Puma concolor*, Western Spotted Skunk, *Spilogale gracilis*, encounter competition, kleptoparasitism, competition, California.

Encounter competition describes non-territorial inter- and intra-specific competition for resources, including access to food and mates (Schoener 1983). Encounter competition, which includes kleptoparasitism (when an individual attempts to usurp or feed on prey killed by another) (Cooper 1991; Murphy et al. 1995; Trinkel and Kastberger 2005; Hebblewhite and Smith 2010), is likely common but is not well reported in the literature. In interspecific encounter competition, smaller species generally avoid larger species (Dickman 1991); however, when species directly interact, the group or individual of the species with more biomass typically wins access to the contested resource (Johnson et al. 1985; Cooper 1991; Gorman et al. 1998; Berger and Gese 2007).

Kleptoparasitism increases in frequency when food resources are scarce, search time for food is high, or, as in other forms of encounter competition, there is asymmetry between the two competitors—meaning that larger, more powerful kleptoparasites more easily and more often steal from physically inferior species or conspecifics (van der Meer et al. 2011; Broom and Ruxton 2003). Scavengers directly decrease carnivore energetic intake and fitness, are responsible for an increase in kill rates, and indirectly alter predator–prey dynamics of ecosystems (Gorman et al. 1998; Krofel et al. 2012; Elbroch and Wittmer 2013a). For example, kleptoparasitism has been noted in kills made by Gray Wolves (*Canis lupus*) (Hebblewhite and Smith 2010), Coyotes (*Canis latrans*) (Jung et al. 2009), and Cougars (*Puma concolor*) (Ruth and Murphy 2010; Elbroch and Wittmer 2012).

Cougars are large, solitary carnivores that frequently kill ungulates. Cougars also provide a significant food subsidy to scavengers, in comparison with other

carnivores (Ruth and Murphy 2010; Elbroch and Wittmer 2012). Gray Wolves, Brown Bears (Grizzly Bears) (*Ursus arctos*), and American Black Bears (*Ursus americanus*) usurp Cougar kills (Ruth and Murphy 2010). Mesocarnivores, such as Coyotes, Bobcats (*Lynx rufus*), and Gray Foxes (*Urocyon cinereoargenteus*), have also been documented scavenging from Cougar kills without displacing them (Koehler and Hornocker 1991; Boyd and O’Gara 1995; Logan and Sweanor 2001). The numerous species scavenging from Cougar kills may lead to significant food losses, especially when Cougars are displaced from their kills. Here, we describe a series of encounters between a Cougar and a Western Spotted Skunk (*Spilogale gracilis*) feeding from a Black-tailed Deer (*Odocoileus hemionus columbianus*) killed by the Cougar.

Methods

Our observations were made as part of a study on the influence of Cougar predation on a declining Black-tailed Deer population in Mendocino National Forest, California (39.7°N, 122.9°W). We captured Cougars using trained hounds and box traps, chemically immobilized the Cougars, and then fitted them with Argos GPS collars (7000SAW, Lotek Engineering Inc., Newmarket, Ontario). Based on Elbroch and Wittmer (2013b), GPS collars were programmed to acquire GPS locations at 2-hour intervals, and location data were downloaded via satellite connection every three days. We conducted field investigations of ≥ 3 points, including a night-time location, within 150 m of each other to locate potential kill sites. When we discovered active kill sites at which the Cougar was still feeding, we placed motion-triggered video-cameras (Bushnell TrophyCam, Overland Park, Kansas) programmed to

collect 60-second videos with a 1-second delay between triggers over the carcass for 20 days to document the diversity of scavengers that fed on it.

Results

On 22 November 2011, we discovered a Black-tailed Deer killed by Cougar F23 approximately 10 hours previously. F23 was an adult female originally captured in June 2011 and estimated to be 4.4 years of age, based on gumline recession (Laundre et al. 2000). During capture, we noted the Cougar as being in very good health (based on fat deposits, pelage condition, and lack of external parasites). She was a large female, weighing 49.5 kg.

The carcass was in a small drainage within a montane hardwood habitat underneath a cluster of scrub oaks (*Quercus* spp.). The carcass was very fresh; the Cougar had removed only minimal organs and had not yet cached it. The Black-tailed Deer was a female and was 3.5 years of age based on molar wear patterns (Heffelfinger 2010*). The video-camera was placed on a tree 2.5 m away, and the carcass was anchored to a tree with a wire cable.

Before the encounter, the Cougar returned and fed from the carcass for three days. During this time, she visited the carcass seven times, with visits lasting a mean of 34.3 minutes (SD 6.7). On 25 November 2011, a Western Spotted Skunk was detected at the carcass at 21:54. The Western Spotted Skunk investigated the carcass and left 1 minute later. The Cougar returned to the carcass 4.3 hours later and fed on the carcass for 24 minutes, at which point she noticed the Western Spotted Skunk arriving from a distance. As the Western Spotted Skunk approached, the Cougar backed away from the carcass. The Western Spotted Skunk then approached the carcass and began feeding. After feeding for 3 minutes, the Western Spotted Skunk moved aggressively towards the Cougar, causing her to hiss and quickly leave the area. Based on the pattern of markings on the coat of the Western Spotted Skunk, we believed it to be the same individual that originally investigated the carcass.

The Cougar returned 20 minutes later and cautiously approached the carcass. The Cougar spent 1 minute alternating between smelling the carcass and visually searching the area. The Western Spotted Skunk then came out from beneath a nearby rock and rushed toward the Cougar, causing her to growl and jump back out of the way. The Cougar moved about 4 m away from the Western Spotted Skunk, up the bank from the carcass. The Western Spotted Skunk spent 18 seconds inspecting the carcass and then moved uphill directly towards the Cougar. When the Western Spotted Skunk approached within 1 m of the Cougar, she retreated and again moved off. The Western Spotted Skunk returned to the carcass and spent 3 minutes feeding before leaving.

The Cougar returned once again at 5:04 (3 hours later) and slowly approached the carcass. She smelled and investigated around the carcass for 3 minutes before she began to feed. The Western Spotted Skunk approached the carcass 12 minutes later. Upon arrival, the Western Spotted Skunk quickly approached the carcass. Instead of retreating, the Cougar hissed and bared her teeth at the Western Spotted Skunk, causing the Western Spotted Skunk to back up, away from the carcass. The Western Spotted Skunk then circled around the bottom side of the carcass before cautiously approaching the carcass again. The Western Spotted Skunk then began feeding on the downhill side of the carcass while the Cougar continued to feed on the uphill side. The Western Spotted Skunk fed actively on the carcass for 2 minutes before leaving the carcass, and the Cougar fed for another 51 minutes before leaving.

The Cougar returned once more on the evening of 26 November 2011 for a 9-minute visit before abandoning the carcass. There were little edible remains left on the carcass at this point. It was monitored for 15 more days, and visits by a Bobcat and a Fisher (*Martes pennanti*) were recorded, but neither the Cougar nor the Western Spotted Skunk were detected again.

Discussion

During these encounters, the Western Spotted Skunk appeared to initially rely upon tail-lifting in order to threaten to spray the Cougar, while also appearing to communicate its aggressiveness to the Cougar through body language. After the initial encounter, the Western Spotted Skunk appeared to rely less on threats of spraying and instead just used aggressive body language in its direct encounters with the Cougar. Hunter (2009) found evidence that potential Striped Skunk (*Mephitis mephitis*) predators learn from experience not to engage skunks and that, through experience, predators learn the implied threat in aposematic coloration. It may be that this Cougar had had past encounters with either Western Spotted Skunks or Striped Skunks and had learned to avoid, rather than confront, them.

Western Spotted Skunks typically weigh about 0.5 kg (Jameson and Peeters 2004). In this series of encounters, a Western Spotted Skunk temporarily usurped a carcass from a Cougar weighing about 99 times more than the Western Spotted Skunk. Our observation is in contrast to most published information on encounter competition, where the larger species displaces the smaller species. We believe that this is the largest reported size differential for the smaller mammalian species winning such an encounter against a larger species. There have been unsubstantiated anecdotal reports of relatively small-bodied Wolverines (*Gulo gulo*) usurping prey from larger-bodied carnivores, but the body size differential is likely not as great as

we observed between a Western Spotted Skunk and a Cougar. Our observations, along with those described for challenge commonly held beliefs about which species will win encounter competition events and should lead us to consider factors other than the size or biomass of the competing species.

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Supplementary video available at:
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Plant Climbing in the Northern Two-lined Salamander, *Eurycea bislineata*, in Algonquin Provincial Park, Ontario

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LeGros, David, L. 2013. Plant climbing in the Northern Two-lined Salamander, *Eurycea bislineata*, in Algonquin Provincial Park, Ontario. *Canadian Field-Naturalist* 127(1): 67–69.

Lungless salamanders (Plethodontidae) are often active on the surface on rainy evenings, and some species may even climb vegetation in search of prey. Here I report the first investigation of plant climbing in the Northern Two-lined Salamander (*Eurycea bislineata*). Surveys were carried out along Bat Lake Creek in Algonquin Provincial Park over four rainy nights in summer 2007 for Northern Two-lined Salamanders. I compared the numbers of Northern Two-lined Salamanders foraging on the ground with those climbing on plants, and over half of the Northern Two-lined Salamanders were climbing plants. This behaviour may provide the Northern Two-lined Salamander with access to an underutilized food source, and plants may represent an additional foraging habitat for this species.

Key Words: Northern Two-lined Salamander (*Eurycea bislineata*), plant climbing, foraging, Algonquin Provincial Park, Ontario.

Lungless salamanders (Plethodontidae) are important components of forest floor and stream ecosystems in eastern North America, providing the majority of small vertebrate biomass in some forests (Burton and Likens 1975a, 1975b). Most studies of the prey items of these salamanders have sampled stomach contents from Eastern Red-backed Salamanders (*Plethodon cinereus*) collected in the leaf litter (Jaeger 1978, 1980), reinforcing the assumption that lungless salamanders restrict their foraging to the immediate substrate. However, lungless salamanders may forage in other habitats, exploiting invertebrates, such as phytophagous insects, not normally associated with forest leaf litter.

Lungless salamanders are extremely sensitive to environmental conditions, such as ambient air temperature and soil moisture (Spotila 1972). When exposed to dry conditions, lungless salamanders rapidly lose water and have a restricted foraging time (Feder and Londos 1984). Similarly, during dry periods, prey may also be limited, further reducing foraging opportunities (Jaeger 1980). To avoid dry conditions, lungless salamanders seek refuge under cover, where humidity remains consistently high. Typically, lungless salamanders emerge to forage at night or under wet conditions (Spotila 1972).

On rainy nights, Eastern Red-backed Salamanders have been observed climbing plants, presumably to exploit underutilized food sources (Jaeger 1978). Although Eastern Red-backed Salamanders and Northern Two-lined Salamanders (*Eurycea bislineata*) have similar diets and body sizes (Petranka 1998), plant-climbing behaviour has not been documented in the Northern Two-lined Salamander. After a thorough review of the literature, I believe this is the first report of plant climbing in the Northern Two-lined Salamander. I report the results of a survey to determine the frequency of plant-climbing behaviour of the Northern Two-lined Salamander in central Ontario, near the northern limit of the species' range (Petranka 1998).

Methods and Materials

Surveys of Northern Two-lined Salamanders were conducted on four nights between 23 June and 29 August 2007 along Bat Lake Creek, a small stream in Algonquin Provincial Park, Nipissing District, Ontario (45°35'N, 78°32'W). After dark on rainy evenings, or following an afternoon rain (2000 to 2330), 1–7 people surveyed Bat Lake Creek by walking the banks and visually searching for salamanders active on the surface. We watched for salamanders on rocks and debris or climbing on vegetation in the stream or on the stream bank within 1 m of the water's edge. When one was located, its location (on the ground or elevated on a plant or log) was noted. Salamanders were considered to be "on the ground" when observed in the open on leaf litter overlying the soil substrate, and were considered to be "climbing a plant" when found above the soil-litter substrate on live or dead vegetation.

All Northern Two-lined Salamanders observed were captured, after which they were sexed (based on presence or absence of the mental gland) (Petranka 1998), and snout–vent (SVL) and total length (TL) were measured with Vernier callipers. Northern Two-lined Salamanders were then released at site of capture.

Area surveyed was measured with a vinyl tape and calculated as stream length \times stream width, the latter incorporating 1 m of stream bank on each side of the watercourse. Nightly sampling effort is here defined as the number of total person-hours of sampling per night. A χ^2 test of independence was conducted to determine whether there was a significant difference between the number of Northern Two-lined Salamanders on the ground and climbing on plants.

Results

During four night-time sampling events between 23 June and 29 August 2007, 19 adult Northern Two-lined Salamanders were captured. The average snout–vent length of these individuals was 31.8 mm (SD 1.3).

TABLE 1. Locations of Northern Two-lined Salamanders (*Eurycea bislineata*) (on the ground or climbing plants) captured along Bat Lake Creek, Algonquin Park, Ontario, in summer 2007. Effort is defined as the number of hours spent searching the creek and bank (1 m on each side of the stream bank) × the number of persons searching; the area (m²) was defined as the length of stream × the width of the stream and 1 m on each stream bank.

Date (2007)	# Salamanders on Ground	# Salamanders Plant Climbing	Total	Persons	Effort (hours)	Area (m ²)	Salamanders per hour	Salamanders per m ²
23 June	0	1	1	1	1	90	1	0.01
8 July	3	7	10	3	4.5	222	2.22	0.04
14 July	4	0	4	2	1.33	105	3.00	0.03
29 August	1	3	4	7	7.58	150	0.52	0.02
Total	8	11	19	13	14.41	567	1.31	0.03

Eight of the Northern Two-lined Salamanders were on the ground in the open and around rocks, and 11 were on vegetation and fallen logs, ranging from 10 to 45 cm above the ground (Table 1). The χ^2 test revealed no difference between Northern Two-lined Salamanders on the ground and climbing plants ($\chi^2 = 7.30$, $df = 3$, $P = 0.06$).

Discussion

Nocturnal surface activity of stream-dwelling salamanders commences at dusk and peaks approximately 1 hour after dark (Holomuzki 1980). In the study reported here, just over half of the 19 Northern Two-lined Salamanders observed on wet nights were climbing vegetation. Although there was no significant difference between the number of Northern Two-lined Salamanders on the ground and climbing plants, it does suggest that plant-climbing behaviour is common at this location.

Jaeger (1978) reported that Eastern Red-backed Salamanders climb plants to gain access to an underutilized food source – plant-dwelling insects. Jaeger (1978) also suggested that climbing single stems and foraging for insects on the foliage provided a two-dimensional habitat that was less complex than the three-dimensional habitat in the leaf litter, thus facilitating the capture of insects. The value of plant-climbing behaviour as an important foraging technique for these salamanders is further supported by Jaeger’s (1978) work, which revealed that Eastern Red-backed Salamanders that climbed plants had significantly greater volumes of arthropod prey in their stomachs than individuals found in the leaf litter. Jaeger (1978) also found that these plant-climbing Eastern Red-backed Salamanders had larger prey items in their stomachs, mainly plant-dwelling insects (Hemipterans and Homopterans), than those foraging in the leaf litter.

Although I did not collect Northern Two-lined Salamanders to analyze the stomach contents, it seems likely that Northern Two-lined Salamanders engaging in plant climbing were consuming arthropod prey captured on vegetation. It is also noteworthy that the timing of plant-climbing behaviour (the hours after sunset) coincides with peak activity of plant-dwelling insects (Holomuzki 1980).

Northern Two-lined Salamanders typically inhabit streams and seeps (Petranka 1998), but they are known to venture considerable distances into the adjacent forest (MacCulloch and Bider 1975). The surveys presented here were limited to the stream bank (within 1 m of the stream edge); therefore, any individuals further away from the stream, whether in the leaf litter or climbing on vegetation, were not captured. Because Northern Two-lined Salamanders were not looked for under rocks, many individuals were likely not counted.

This is the first report of plant climbing in the Northern Two-lined Salamander. However, this behaviour is not unexpected. In addition to the Eastern Red-backed Salamander, other *Plethodon* ssp. and juvenile *Ambystoma* ssp. have been observed climbing plants (Burton and Likens 1975a; Jaeger 1978; Smith et al. 2011; Osbourn et al. 2012). Generally, salamanders within the genera *Plethodon*, *Aneides*, and *Eurycea* are competent climbers, and some salamander species live in vertical habitats, such as trees, rock crevices, cliffs, and caves (Noble and Marshall 1929; Stebbins 1951; Peck and Richardson 1976).

Lastly, due to the secretive and nocturnal nature of Northern Two-lined salamanders, plant climbing in this species may have been noted previously but not published. One such opportunistic observation was made of a single Northern Two-lined Salamander (Canadian Museum of Nature 2834, 2 km south of Bishopton, Quebec, 4 June 1954, collected by J. S. Bleakney and F. R. Cook) climbing on a stem projecting above the water among tufts of grass among a *Pseudacris crucifer* (Spring Peeper) chorus in a flooded field with a stream flowing through it (F. R. Cook, Canadian Museum of Nature, personal communication, 2013).

New techniques to study the movements of salamanders, such as using fluorescent powders (Smith et al. 2011), may yield new observations of plant climbing in other species in the future. If stream salamanders regularly make forays into stream-side habitats and climb plants in search of prey, conservation of both streams and their adjacent riparian habitat may be required to maintain populations.

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Age Structure of Moose (*Alces alces*) Killed by Gray Wolves (*Canis lupus*) in Northeastern Minnesota, 1967–2011

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Mech, L. David, and Michael E. Nelson. 2013. Age structure of Moose (*Alces alces*) killed by Gray Wolves (*Canis lupus*) in northeastern Minnesota, 1967–2011. *Canadian Field-Naturalist* 127(1): 70–71.

The ages of 77 adult Moose (*Alces alces*) killed by Gray Wolves (*Canis lupus*) during the period 1967–2011 in northeastern Minnesota were significantly older than those of a sample of 17 585 Moose killed by hunters in nearby Ontario. Our findings support those of earlier studies of protected Moose populations in national parks that found that Gray Wolves tend to kill disproportionately more older Moose.

Key Words: *Canis lupus*, Gray Wolf, *Alces alces*, Moose, predation, hunting, Minnesota, Ontario.

The age structure of Moose (*Alces alces*) killed by Gray Wolves (*Canis lupus*) is available from only two national parks in the United States where hunting by people is not allowed and from three areas in Alaska where Moose are hunted (Mech 1966; Peterson et al. 1984; Ballard et al. 1987; Mech et al. 1998). The samples of Moose killed by Gray Wolves from each hunted area are relatively small (47–117), given that Moose live to 20 or more years (Passmore et al. 1955). This article adds age data from another 77 Moose killed by Gray Wolves from a fourth (lightly) human-hunted area and assesses the age structure of all the samples.

This study was conducted as part of a radio-tracking study of Gray Wolves in the Superior National Forest in northeastern Minnesota (48°N, 92°W) (Mech 2009). There, Gray Wolves prey on both White-tailed Deer (*Odocoileus virginianus*) and Moose. The point estimates of the Moose population in the region varied from 2140 to 8840 between 1971 and 2011 (J. Giudice, Minnesota Department of Natural Resources, personal communication and M. Lenarz, Minnesota Department of Natural Resources, personal communication). Since 1971, Moose hunting on a lottery basis has been allowed, and about 200 Moose per year have been harvested (Edwards et al. 2004).

Of 107 Moose killed by Gray Wolves that we located by aerially radio-tracking Gray Wolves from 1967 through 2011, we examined 85 that we could sex; 45 were females and 40 were males. We collected teeth from 37 cows and 26 bulls from among the 85 and from 14 Moose from among the 22 of unknown sex (total 77 Moose). Mattson's Laboratory (Milltown, Montana) aged the teeth by cementum analysis (calves were probably underrepresented because there are fewer of their remains to find). The age structures of the two sexes were not significantly different (Kolmogorov-Smirnov test; $P > 0.40$). We therefore pooled them and added the unknowns that we could age. The ages of our sam-

ple varied from calves >6 months old to bulls 13 years old and a cow 19 years old (Figure 1).

The best, and about the only, age-structure data available for a hunted Moose population are those for 17 585 Moose killed by hunters in north-central Ontario, presumably a representative estimate of the Moose population at large (Timmermann and Rempel 1998). The age structure of our sample killed by Gray Wolves was significantly different from that of the Ontario population (Kolmogorov-Smirnov; $P < 0.0001$).

Peterson et al. (1984) plotted ages of Moose killed by Gray Wolves from various areas in Alaska in 6-year age classes (1–6, 7–12, and 13+). Of our sample of adult Moose killed by Gray Wolves, only 34% were 1–6 years old, similar to the 27% in the sample in Alaska in Peterson et al. (1984) (no significant difference), whereas 76% of the Ontario population was of this age class ($\chi^2 = 68.55$; $P < 0.0001$). Assuming that the

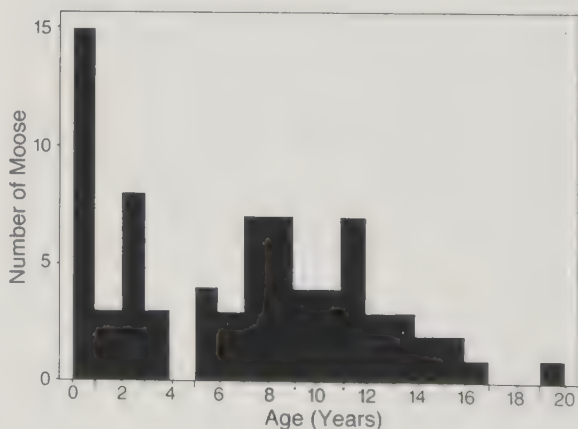


FIGURE 1. Age distribution of 77 Moose (*Alces alces*) killed by Gray Wolves (*Canis lupus*) in northeastern Minnesota between 1967–2011. (Calves are probably underrepresented.)

age structure of the Ontario Moose population at large reasonably approximates that of the study population in Superior National Forest, this is strong evidence that Moose 1–6 years of age are the least vulnerable to Gray Wolves in this area.

We have long known that Gray Wolves tend to kill a disproportionate number of older Moose and calves and that a disproportionate number of younger Moose > 1-year of age survive Gray Wolf predation (Mech 1966; Peterson 1977; Haber 1977; Peterson et al. 1984; Ballard et al. 1987; Mech et al. 1998). However, the actual age when disproportionate vulnerability begins may vary. Peterson et al. (1998) showed that Moose ≥ 9 years of age were more vulnerable on Isle Royale and those >12 years of age on the Kenai Peninsula were more vulnerable (Peterson et al. 1984).

In our sample, Moose ≥ 9 years old comprised 39% of the Moose >1 year of age killed by Gray Wolves, whereas Moose ≥ 9 years old comprised only 10% of the Ontario sample of Moose >1 year of age killed by hunters ($P < 0.0001$; $\chi^2 = 68.29$; 1 d.f.). Thus our study tends to confirm the findings on Isle Royale (Peterson et al. 1998) and adds to the general conclusion that Gray Wolves tend to kill older Moose, whether in populations hunted by people or not.

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Indirect Cannibalism by Crèche-aged American White Pelican (*Pelecanus erythrorhynchos*) Chicks

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At nesting colonies of American White Pelicans (*Pelecanus erythrorhynchos*), many chicks die from siblicide, severe weather, and disease; this results in carcasses available for scavenging by conspecifics (i.e., indirect cannibalism). Indirect cannibalism has not been reported previously for this species. We describe five cases of crèche-aged American White Pelican chicks consuming or attempting to consume dead younger chicks at two nesting colonies in the northern plains of North America. Cannibalism in the American White Pelican appears to be rare and likely plays no role in the species' population ecology or dynamics; however, it might be an important survival strategy of individual chicks when food resources are limited.

Key Words: American White Pelican, *Pelecanus erythrorhynchos*, indirect cannibalism, conspecific scavenging, colonial waterbirds, northern plains, North Dakota, South Dakota.

Cannibalism (ingestion of a conspecific) has been observed across many taxa, including birds—most commonly in hawks, owls, and waterbirds (Fox 1975; Polis 1981; Elgar and Crespi 1992; Stanback and Koenig 1992). Stanback and Koenig (1992) defined cannibalism as the consumption of any part of a conspecific egg or individual. This would include the scavenging of dead conspecifics, which was termed “indirect cannibalism” by Smith and Munro (2008) and “conspecific scavenging” by McGehee et al. (2008).

Many hypotheses have been proposed to explain the prevalence and role of cannibalism in nature (for a review, see Fox 1975; Elgar and Crespi 1992); cannibalism often is associated with food limitation. However, Fox (1975) argued that cannibalism is not confined to food-stressed individuals, and could involve other factors, such as density-dependence, physiological and psychological stressors, cannibal and victim behaviors, and victim availability.

Among avian taxa that display cannibalistic behavior, cannibalism often is restricted to the consumption of eggs and very young chicks because the majority of birds are gape-limited, excluding raptors and a few other taxa that are capable of dismembering prey (Mock 1984). In colonial-nesting waterbirds, cannibalism is an unusual behavior, but can be a notable source of mortality. For example, Davis and Dunn (1976) reported that Lesser Black-backed Gull (*Larus fuscus*) adults that had lost their young frequently cannibalized their neighbors' eggs. Safina and Burger (1983) noted that Black Skimmer (*Rynchops niger*) chicks occasionally ate younger conspecifics, ostensibly in response to human disturbance. On four different occasions, Chapman (1908) observed nearly full-grown Brown Pelican (*Pelecanus occidentalis*) chicks consume younger chicks when the adults had departed from the nests, and Cahn (1922*) observed Brown Pelican adults consume crèche-aged chicks (i.e., those old enough to

disassociate from their nest bowls and gather into groups) that relentlessly begged for food from unrelated adults. Daigre et al. (2012) reported three cases of full-grown Peruvian Pelican (*Pelecanus thagus*) fledglings attacking or consuming younger, unrelated conspecifics from unguarded nests. Gubiani et al. (2012) recorded several instances in which large immature chicks of the Socotra Cormorant (*Phalacrocorax nigrogularis*) consumed young chicks in unattended nests. Riehl (2006) found widespread cannibalism by Black-crowned Night-Heron (*Nycticorax nycticorax*) fledglings, which attacked nestlings or younger fledglings that had fallen or climbed out of nests.

Indirect cannibalism has been reported in several semi-colonial and colonial-nesting waterbirds, including the Socotra Cormorant (Gubiani et al. 2012), Australian Pelican (*Pelecanus conspicillatus*) (Smith and Munro 2008), Black-crowned Night-Heron (Riehl 2006), American White Ibis (*Eudocimus albus*) (Herring et al. 2005), Australian White Ibis (*Threskiornis molucca*) (Smith and Munro 2008), and South Polar Skua (*Stercorarius maccormicki*) (Pietz 1987). Indirect cannibalism also has been reported in non-colonial birds such as the Black Vulture (*Coragyps atratus*) (McGehee et al. 2008), Lesser Yellow-headed Vulture (*Cathartes burrovianus*) (Clinton-Eitnien and McGehee 1994), King Vulture (*Sarcoramphus papa*) (in captivity) (Clinton-Eitnien and McGehee 1994), and American Coot (*Fulica americana*) (Paullin 1987).

The American White Pelican (*Pelecanus erythrorhynchos*) consumes a variety of prey items during the breeding season, including fish, crayfish, and salamanders (Findholt and Anderson 1995; Knopf and Evans 2004). There are no published records of direct or indirect cannibalism in this species. Here, we report evidence of indirect cannibalism by American White Pelican chicks.

Methods

Study areas

We collected data from two American White Pelican breeding colonies in the northern plains of North America: Chase Lake in Chase Lake National Wildlife Refuge in central North Dakota (47°01'N, 99°27'W) and Bitter Lake in northeastern South Dakota (45°16'N, 97°19'W) (see Sovada et al. 2008 for description of study areas). These two colonies are among the four largest American White Pelican colonies in North America. Chase Lake had 17 302, 11 262, and 11 541 American White Pelican nests in 2006, 2007, and 2008, respectively; Bitter Lake had 14 762, 14 713, and 12 946 American White Pelican nests in 2006, 2007, and 2008, respectively.

Data collection

As part of a larger study of the American White Pelican at Bitter Lake and Chase Lake, we closely monitored the colonies for disease outbreaks, predation, and consequences of severe weather and disturbance. We collected data on nesting activities, behaviors, and interactions of American White Pelican adults and chicks from several remote vantage points (e.g., boat, mainland shore) and, when on the islands, from camouflaged blinds and observation points hidden from the American White Pelicans' view.

In addition, we deployed digital video-camera systems near nests to monitor nesting adults and their chicks. The camera systems consisted of a high-quality digital video-camera in a waterproof housing, a digital video-recorder in a weatherproof box, two sealed lead-acid AGM (absorbed glass mat) batteries (each with ≥ 100 amp-hour capacity), and a 120-watt solar panel. Time-lapse recordings from the cameras were used to document diurnal and crepuscular activities of American White Pelicans, focusing on parental care of chicks that were still in the nest. Each field of view in video-recordings included multiple American White Pelican nests.

In 2006–2008, we collected over 25 470 hours of digital recordings of American White Pelican nests. We viewed all recordings. When transcribing data from the recordings, we selected a sample of nests in close view of the camera and we quantified behaviors at those nests. In addition, we noted unusual events and behaviors, such as disturbances, predation, and sibling aggression. Behavioral data were collected largely from the late-incubation stage until chicks began to crèche (i.e., aggregation of chicks from multiple broods). This typically occurs when American White Pelican chicks are about 17 days old (Evans 1984). After the chicks formed crèches, they spent most of their time away from the nest sites, but they were occasionally in the camera's field of view.

Ages of live and dead chicks were estimated by using known hatch dates, culmen length, feather development, and chick size. The ages of some dead chicks were difficult or impossible to determine due to vari-

ability in decomposition rates, which can be influenced by temperature, moisture, insect activity, and exposure to sun or shade. In certain cases, the estimate of the dead chick's age was based on approximate lengths of leg and wing bones.

Observations

Many chick carcasses were observed at the two American White Pelican colonies during 2006–2008; most carcasses were scavenged by gulls or quickly decomposed. A total of five cases or attempts of indirect cannibalism by crèche-aged American White Pelican chicks were recorded at the nesting colonies at Bitter Lake (two cases and one attempt) and at Chase Lake (two cases). Three of the cases were digitally recorded on video; one case was documented by direct observations and photographed from a blind; and one attempt was recorded by video and observed directly. All cannibalistic birds appeared to be in good to excellent condition and lacked any visible injuries.

We also observed several instances of adults tossing eggs or nestlings from their own nests or from the nests of other American White Pelicans, and we observed one instance (Case 1) of chicks in a crèche fighting over a dead conspecific as surrounding adults jabbed at the carcass (Bitter Lake on 2 June 2006). We never observed an adult American White Pelican consuming a chick.

Case 1 (visual and video)

On 2 June 2006, at Bitter Lake, a 21-day-old chick in a crèche with 11 other similar-aged chicks was observed retrieving a dead 18-day-old chick from the ground and repeatedly attempting to swallow the entire carcass. However, part of the carcass was entangled with a stick, which wedged perpendicularly in the cannibalistic chick's bill, preventing the chick from swallowing the carcass. The carcass was exposed in the chick's pouch and vulnerable to theft by other chicks; two other crèche-aged chicks reacted by chasing the chick and jabbing at both the chick and the carcass.

Almost immediately, two adult American White Pelicans entered the crèche and jabbed at the carcass. One of the adults jabbed at the chick's bill, knocking the carcass to the ground, and the two adults fought over it. The first adult flipped the carcass into its pouch, then quickly dropped the carcass and walked away within seconds after stealing it. The behavior was similar to that observed when adults steal food items from each other. Ten minutes later, a chick repeatedly tried to swallow the carcass while being harassed by other crèche-aged chicks, but again the stick prevented successful consumption of the carcass.

Case 2 (visual and photograph)

On 16 June 2006, at Bitter Lake, a 21-day-old chick was observed regurgitating the carcass of another American White Pelican chick. The remains were partially digested, but the bones appeared intact. The con-

dition and level of decomposition of the regurgitated carcass made estimation of its age difficult, but the length of the leg and wing bones suggested that the chick was ≤ 15 days old.

Case 3 (video)

On 12 June 2007, at Chase Lake, a 24-day-old chick swallowed the carcass of a 20-day-old chick whole. The cannibalistic chick was alone, with no other solitary or crèched chicks nearby. Later that day during a rainstorm, the chick was observed being brooded by an adult that was not its parent.

Case 4 (video)

On 13 June 2007, at Chase Lake, two 25-day-old chicks visited the carcass of a chick approximately 15–20 days old. During a 5-hour span, one of the chicks returned to the carcass five different times, tearing off pieces of the carcass and consuming them. The second chick jabbed at the carcass several times but did not appear to consume any of the carcass.

Case 5 (video)

On 10 June 2008, at Bitter Lake, a crèche of four chicks of similar age (~21 days old) was observed pulling off and swallowing pieces of a dead conspecific 15–20 days old. The chicks jabbed and tugged at the carcass repeatedly until they were able to tear off pieces of the rotten flesh. In both cases 4 and 5, chicks did not hold the carcass down with their feet to facilitate tearing, but rather depended on repetitive tugging against the weight of the carcass to separate pieces they could swallow.

Discussion

During 2006–2008, we documented five cases (one attempted and four successful) of indirect cannibalism at two intensively monitored American White Pelican colonies in the northern plains. Human disturbance at the colonies was minimal, and we have no evidence that the cannibalistic behaviors that we observed were related to investigator-induced aggression.

Four of the five victims were dead when consumed and one was discovered in regurgitate of the cannibal, thus the status of the victim when consumed was unknown. All cannibalistic events or attempts involved crèche-aged chicks consuming younger chicks. The average age of the cannibalistic chicks was 23 days and the victims were estimated to be ≤ 20 days old. All cannibalism was observed within relatively small crèches (average 3 chicks/crèche), whereas most crèches contained 6 or more similar-aged chicks. We do not know if any of the cannibals were related to the chicks that they consumed.

Sibling aggression and siblicide were common at nests with chicks in both colonies during our observations (M. A. Sovada and P. J. Pietz, unpublished data). Johnson and Sloan (1978) similarly reported that the smaller nestling died from aggression by its larger

sibling in 90% of two-chick nests that they observed at Chase Lake. Brood reduction by siblicide occurs when chicks are small and nest bound, and when food provisioning by adults is usually adequate (Cash and Evans 1985). During periods when adults are forced to travel greater distances and spend more time away from the colony to forage (e.g., during a drought period), some chicks might die as a result of inadequate food provisioning (Johnson and Sloan 1978). Despite the high incidence of sibling aggression and siblicide in these nesting colonies, we did not note any cases of nestlings killing and then eating nest mates or of adults killing or eating their offspring (i.e., filial cannibalism). Siblicide in birds rarely leads to cannibalism (Mock et al. 1990).

Although siblicide contributed to high mortality of nestlings in these colonies, the greatest loss of older or crèche-aged chicks resulted from unfavorable weather during late May through mid-June and outbreaks of West Nile virus in mid-July through August (Sovada et al. 2008). All five cannibalistic events occurred in early to mid-June, and all but one attempt immediately followed several days of cold, wet, windy weather.

During periods of poor weather, adult nest attendance and the frequency and duration of chick feedings declined markedly on video recordings. As adult attendance waned, chicks were more vulnerable to the elements and some chicks eventually succumbed to exposure, harassment (by other chicks or unrelated adults), or starvation. This resulted in more carcasses than usual, augmenting cannibalistic opportunities for the surviving chicks. These surviving chicks may have been stressed by hunger and declining nutritional condition, which could have prompted cannibalism. However, in all cases, chicks that we observed cannibalizing conspecifics appeared to be in good to excellent body condition.

Gubiani et al. (2012) noted that opportunistic cannibalism in crèche-aged Socatra Cormorant chicks may have been triggered by starvation and the presence of altricial chicks from late nesting attempts. Daiege et al. (2012) suggested that food deprivation and opportunism might explain aggression and cannibalism by older Peruvian Pelican fledglings.

It is notable that during the late breeding season, when many American White Pelican chicks were killed during an outbreak of West Nile virus (Sovada et al. 2008), no cannibalism was observed. Chicks during this period were already 42–70 days old (Sovada et al. 2008); it is unclear if these carcasses were too large to be consumed by other chicks or if surviving chicks were not stressed by hunger.

Given the rarity of cannibalism during more than 25 000 hours of video-recording and direct observation of two large American White Pelican colonies, cannibalism by older American White Pelican chicks is clearly not affecting chick survival at the population

level. Yet, during periods when food resources are limited, cannibalistic behavior could benefit individual chicks by enhancing their survival.

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Tribute to George F. Ledingham (1911–2006), a Conservation Leader for Western Canada

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“Society ... must take a strong stand for conservation. In a democracy, we cannot expect to have the problems of conservation and wildlife management solved intelligently without an informed public”.

Readers will be forgiven if they think this is a new challenge to Canadians from an expert body that believes the present federal government is on a path of unconscionable suppression of nationally important environmental research and monitoring programs. It is actually a clarion call from the past to the Saskatchewan Natural History Society (SNHS – now Nature Saskatchewan) to refocus itself as an advocate of the protection of natural environmental values in western Canada. And far from being a contemporary challenge, it was written in 1956, over half a century ago.

Saskatchewan native George Filson Ledingham (31 January 1911 – 18 October 2006, Figure 1) wrote that in his capacity as incoming editor of *The Blue Jay*, the excellent natural sciences journal of the SNHS (Ledingham 1956). He was editor for 16 years, reshaping the journal into the premier publication of its kind in the prairie provinces. In the course of his editorship, as in numerous public presentations, deputations to provincial and federal governments, co-operative ventures with various non-governmental conservation organizations, and one-on-one dealings with innumerable fellow naturalists, he was a consistently strong advocate of the need to conserve natural areas and wildlife. It's tempting to say George Ledingham was ahead of his time. It's probably more accurate to suggest that he was very much *of* his time but at the front of the pack.

As noted in the reviews of Ledingham's life and career by Fahselt (2007) and Houston and Nero (2006), conservation action was not his “day job.” His career as a biology professor and well-respected teacher at Regina College (later the University of Regina) extended from 1946 until 1976, continuing with part-time teaching until 1983 (Houston and Nero 2006). He was an authority on the cytology of *Oxytropis* and *Astragalus*, both agriculturally and ecologically important plant genera in the bean (Fabaceae) family that are well represented in prairie landscapes. Fieldwork for his investigation of these plants likely contributed to



FIGURE 1. George Ledingham in 1982. Photo: Gary Seib.

his lifelong love of native prairie and to his tireless efforts to conserve and protect native examples of it.

The prairie was in his blood. George Ledingham was born into a large family with five siblings on a farm west of Moose Jaw, Saskatchewan. Initially trained as a public school teacher, he later obtained a B.Sc. (1934) and M.Sc. (1936) from the University of Saskatchewan, venturing beyond the province to earn a Ph.D. from the University of Wisconsin in 1939. He married University of Saskatchewan graduate (B.A., 1939) Marjorie Clare Beattie in June 1942. He was predeceased by Marjorie in March 2000 but was survived by their son, Beattie, three grandsons, and four great-granddaughters (see Houston and Nero 2006 for further details of his personal background).



FIGURE 2. Native prairie in the Frenchman River valley, Grasslands National Park, Saskatchewan, 1 July 2008. Photo: D. F. Brunton.

Ledingham's notable scientific contributions include his role in the founding and development of the 70 000-specimen herbarium of the University of Regina (USAS) (herbarium acronym follows Thiers 2012). He was also widely credited as being a major influence in developing the careers of his students (Fahselt 2007). His proudest legacy, however, is undoubtedly his success in obtaining protection for important examples of native grasslands. More than that of any other individual, his persistence in conducting research and public education and in lobbying for over 30 years was responsible for the creation in 1989 of Grasslands National Park in southwestern Saskatchewan (Houston and Nero 2006) (Figure 2).

Ledingham's efforts on behalf of the naturalist community in Saskatchewan were exceptional. It is difficult, for example, to overstate his importance in the establishment and early success of the SNHS. In August 1948, when he was President of the Regina Natural History Society, he received a letter from the Yorkton Natural History Society (drafted by C. Stuart Houston) exploring the possibility of provincial co-operation in the publication of their local Yorkton journal, *The Blue Jay*. Ledingham responded positively but went further by suggesting the formation of a province-wide naturalists' federation that would be more than just the publisher of the journal (Belcher 1996). This, the Saskatchewan Natural History Society,

would provide improved communications and support within the provincial naturalist community and offer greater opportunities for both public educational and effective wildlife conservation measures.

Ledingham was appointed provisional president of the SNHS at the 24 January 1949 formative gathering of local natural society representatives in Regina. The following year he became the first president elected by the membership, thus presiding over the crucial early days of the organization and initiating decades of service in various administrative and organizational capacities. A dramatic illustration of the importance and endurance of his involvement is evident in Figure 3. Each coloured page marker indicates a page in Margaret Belcher's comprehensive history of the SNHS where mention of one or more of George Ledingham's contributions to the Society appears.

It is a remarkable record. Throughout his lengthy history of action and concern, however, George Ledingham never lost focus on the need for Saskatchewan naturalists to be well informed about their landscape, to share that knowledge in the pages of *The Blue Jay* and elsewhere, and to be persistent in ensuring that important prairie landscapes were protected.

Amongst the many accolades he received for his long and productive professional and community career was the naming of the University of Regina herbarium in his honour (Anonymous 2006). He continued to con-

duct curatorial and taxonomic work there well into his 90s. The University of Regina also conferred an honorary doctorate on him in November 1986 (Anonymous 1986).

In 1981 he received the J. B. Harkin Medal from the National and Provincial Parks Association of Canada (now Canadian Parks and Wilderness Society) for his contribution to the conservation of native grasslands in the prairie provinces (Belcher 1982).

Ledingham was awarded an Honorary Membership by the Ottawa Field-Naturalists' Club in 1992. The citation includes the following:

"There is a rich and special connection between prairie people and the land. This productive and often eloquent relationship has produced remarkable interpreters of western grasslands, be they writers like W. O. Mitchell, painters like William Kurelek, or scientists like George Ledingham. ... If Black-footed Ferrets once again hunt prairie-dogs on the open Canadian prairie it will happen here and only because of the effort and dedication of Ledingham and his associates" (Brunton 1993).

That the once almost extinct Black-footed Ferret (*Mustela nigripes*) is indeed now hunting Black-tailed Prairie Dogs (*Cynomys ludovicianus*) on the native prairie of Grasslands National Park underscores the importance of that vision and his perseverance.

Like the man himself, one especially important legacy of George Ledingham is understated and subtle. That is his role from the late 1950s into the 1980s as a spokesperson for and interpreter of the conservation ethic that was developing in western Canada and across North America. His well-expressed, science-based writings – especially his editorials in *The Blue Jay* (see appended bibliography) – influenced a generation of western Canadian naturalists.

Here was a man who was totally at home on the prairie, who knew it well, who communicated that knowledge with credibility and respect, and who made a lasting and important contribution to the protection of its native biodiversity. His inspiration continues to pay conservation dividends, in both the work of organizations like Nature Saskatchewan and the initiatives of individual prairie naturalists.

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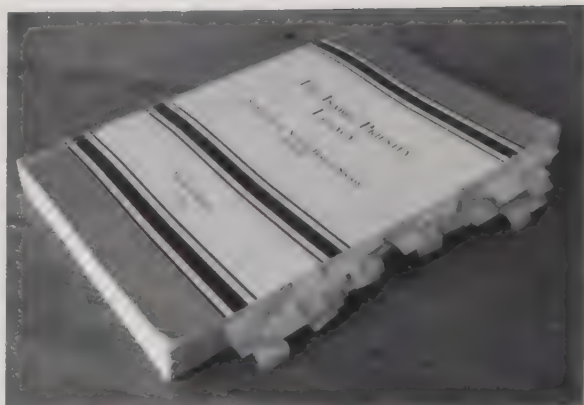


FIGURE 3. Pages marked with numerous Ledingham references in the history of the Saskatchewan Natural History Society (Belcher 1996).

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Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

Editor's Note. The address of the Birds of Northumberland County website has been changed to <http://www.willowbeach-fieldnaturalists.org/Northumberland-County>. This is part of the Willow Beach Field Naturalists' website, but the URL above will take you directly to the Birds of Northumberland County. Please note that the URL is case sensitive. From Clive Goodwin.

ZOOLOGY

Where to Watch Birds in Canterbury (New Zealand)

By Nick Allen. 2012. Toltech Print, 21 Gasson Street, Christchurch, New Zealand. 169 pages, 29.99 NZD, Paper.

New Zealand is a stunningly beautiful country with an odd avifaunal history. The region of Canterbury is a great chunk of land covering half the eastern side of South island. It encompasses the Canterbury Plains and the surrounding mountains. Its main city, Christchurch, is a lovely town set in this scenic landscape. Recently it suffered a devastating earthquake that caused much damage. Happily the wildlife seems to have survived and this new book, written after the quake, will help naturalists find birds in this region.

The book is divided into 14 sections of areas centred around Christchurch that each has a regional map. The sections are further divided into areas that also have a map. The text gives an overview of the sites with brief notes on accommodation and transport. The roads and trails are described, including hazards like mud or floods. The birds that are found at the site are listed under four headings; usual, probable, possible and vagrants. These assessments are honest and do not create false expectations.

The last section of the book is an annotated list of birds and where to find them. For example under Australian Gannet the author suggests looking out from headlands. This I did, without success, but the advice was clearly sound. For Little Black Shag the entry states

tiny numbers can be seen at Bromley Oxidation Ponds. This time I was successful seeing one bird – a tiny number indeed. The author explains that Black-fronted Terns are found on farmland and White-fronted Terns were coastal. This proved valid and I finally saw a small group of Black-fronted Terns over a farm field after searching in vain over the sea. Each species is coded to the sites covered in the guide.

It is a really useful book for the visitor and resident alike. I would have no problems finding all the places and knowing what to look for. That said I would have liked a far clearer regional map, especially if it was colour coded to the 14 chapters. I did find it difficult to orient myself at times. The book does not have an index which adds a little more work to finding items. It would have been nice to have had photographs of birds and locations. At just over \$25 Canadian the book is not expensive so buyers will not mind a few dollars more for a handful of illustrations. Once you have familiarized yourself then the book becomes a useful tool. I would recommend it to all visiting birders and many "Kiwis" will also find it valuable.

ROY JOHN

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The World's Rarest Birds

By Erik Hirschfeld, Andy Swash and Robert Still. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA. 08540-5237. 360 pages, 45.00 USD, Cloth.

This book is a delight and a distress. I expected to find accounts of species I had searched for knowing their rarity. Birds such as Whooping Crane, Bengal Florican, Red-breasted Goose and Brown Kiwi to name a few. Imagine my dismay at seeing a photo of a Eurasian Turtle Dove in the first few pages. This was a bird I saw often in my youth and associated its

soft purring with warm, sunny days. Last March I did not see any in the UK, but assumed (correctly) I was too early. It seems as though this bird is in trouble, having lost 60% of its world population (The RSPB recently quoted a 93% loss for the UK). The Black-browed Albatross was another surprise, until I looked at my notes. On trips south I saw several thousand ten

years ago, a year ago it was a couple of hundred and this year it was 70. While only anecdotal, it is a dramatic change.

So this book is a snapshot of the most recent status of 590 bird species. It is organised, more or less, by continent (Europe and the Middle East; Africa and Madagascar; Asia; Australasia; Oceanic Islands; North America, Central America, and the Caribbean; and South America.). Antarctica is not covered, but Oceania is. Each species has coverage in all the continents where it occurs. So Black-browed Albatross has an entry in the pages on Australasia, the Oceanic Islands and South America. Each species gets coverage of distribution, status, population, key threats, and conservation needs. Birds that appear more than once have a different picture accompanying the write-up.

The text is focussed on the status in each specific region. Each entry has a QR code (abbreviated from Quick Response Code) that can be read by an imaging device, such as a camera or a smartphone (with Android operating system and iOS devices [iPhone/iPod/iPad]) with a QR app. This will access BirdLife International's annually updated website. The authors have included a range map, but these can be hard to read. For example, the maps for the Madagascar Pond-heron and the Amber Mountain Rock Thrush are the same scale. This means the range for the thrush is a tiny dot while the pond-heron's larger distribution is more obvious. The range of the Madagascar Ibis along the west coast of the island is particularly difficult to see. The range maps at BirdLife International's website are far more detailed.

Between the species texts are essays on a variety of topics, such as the Amazon Basin and the special plight of albatrosses, vultures or bustards. There are summaries of the key issues in each region, especially the vulnerable islands (e.g. the Galapagos, New Caledonia, Hawaii etc). Less usual are accounts of the world's most threatened flyway and grassland management.

The photographs in this book are remarkable. Most are not of birds in spectacular positions – displaying, feeding chicks and the like – but are portraits, a more suitable pose for this book. Birds are shown perched, standing or flying in postures an observer would likely see in the field. They are photographs worthy of Yousuf Karsh, that master of human portraits of states-

men, artists, scientists, and other humans of renown. When I look at my attempts this year to photograph Brown Kiwi or Yellow-eyed Penguin I can appreciate the amazing quality of these photographs. The authors got these lovely pieces of art in a novel way – they ran an international photography competition. This gave them a choice of over 3,500 images for all but 76 of the target species. For these latter birds they engaged Tomasz Cofta to paint illustrations. For a species like the beautiful Bates Weaver, last seen in 1998, Cofta has produced a stunning portrait that fits well with all the photographs on the page.

Photographs are also used as a compliment to the essay text. This is achieved as inserts, backgrounds, margins and full page features. The result is a book that could pass as a coffee-table tome. But this is far more than a picture book. Yet I do not recommend you read this book as it can be very depressing. Too many of the birds that excite us are in sad and serious trouble. I soon found I was grabbing the book to look up a burning question which led to more questions and more reading. Then I would take a rest. Clearly it is a great reference that will unfortunately become dated in a horrifyingly short time.

While I was upset by a number of birds that have reached a critical status, I was surprised that some species were not included. I spent some time chasing Saint Vincent Parrot (an island species, population less than 1000 in an area of 389 km²) that only reaches Vulnerable status. I read through the thresholds for IUCN Red Listing and I am still unclear why this bird does not have a “higher” status leading to a more concerted conservation effort. The other bird that came to mind was the (New Zealand) Saddleback (population about 7000), but the South Island form has gone from a low of 36 to a current 700.

Despite its message this is a wonderful book. It will be an essential resource for serious ornithologists and researchers involved in conservation. There is a cadre of wealthy, travelling listers who will find the information in this book essential in their pursuit of new ticks. Bird photographers will love the photos and Cofta's reputation will surely rise.

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Concealing Coloration in Animals

By Judy Diamond and Alan B. Bond. 2013. Belknap Press-Harvard University Press, 79 Garden Street, Cambridge, MA, USA, 02138. 288 pages, 29.95 USD, Cloth.

I have always found colour fascinating. As a naturalist this is an even more intense interest. So this new book was an ideal one for me to read. I began reading with high hopes and I was not disappointed. The authors were concerned, not with how the colours are created, but with the way they are used. We have all

heard the oft-repeated phrases about camouflage, dazzle patterns and sexual attraction. There is some truth to these ideas, but there many questions raised about the validity of these “accepted” concepts. How many times have we seen a warbler with a beak full of green caterpillars? If a green bug on a green leaf cannot

escape detection then what good is camouflage? We have all seen videos of African Lions bringing down a Burchell's Zebra. So what value has dazzle pattern? Eastern Wood-Pewee is not the most dazzling species yet they do get mates. So why does the same wood lots house the fluorescent Baltimore Orioles?

Diamond and Bond explain what we know of the evolution of concealing colouration and how it fits into concealment strategy. They describe how this works and what are the flaws that allow predators to get their food. For humans it is hard to see these flaws as camouflage generally fools us. A couple of years ago I bought an expensive green laser because I had been so frustrated by animal camouflage. I have spent almost an hour pointing out a hummingbird on its nest or a sleeping Common Night hawk. The laser relieves this problem. A photograph in the book of a desert mantid reminded me of the time I tried to point one out to a group. It took several minute for most of the group to see it, despite holding my finger one centimetre above its head. Eventually I gently nudged its rear and it moved one leg and then the last three people picked it out.

In discussing mimicry the line blurs with camouflage. Does a stick insect or a caterpillar mimic a twig or is it very clever concealment? In North America the Monarch butterfly is a legend. The Viceroy is its mimic – or is it the other way around? The Monarch is toxic, but the Viceroy is distasteful, so who mimics who? Or do they both benefit by being similar?

The Crossley ID Guide: Raptors

By Richard Crossley, Jerry Liguori, and Brian Sullivan. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 286 pages, 29.95 USD, Paper.

Richard Crossley and two foremost raptor experts, Jerry Liguori and Brian Sullivan, have produced a field guide on North America's 34 diurnal raptors that represents a paradigm shift in field guide production. Typically, wildlife field guides, especially those focusing on birds, show static side views of each species, with field marks highlighted. Crossley et al. have instead assembled double-paged field plates that show birds in action from various angles (2 pages for rare species and 4 pages for common species). The layout background shows the typical habitat the raptors occur and mixes adult birds with juveniles. Below each multi-page layout is text providing biological and ecological information for the raptors featured in the layout, including general dimensions, appearance, and the page where the general account can be found. Information about migration and behaviour is highlighted and is an easy read.

The authors have written in their Preface some suggestions on how to use their unique guide, such as study the plates before reading the text – try to figure

The value of bright colour is to attract mates we are told. There are healthy populations of the world's most colourful birds so they avoid predation and still get mates. Then there are all those Little Brown Jobs that skulk out of sight. They also avoid predation and get mates.

As well as considering the forms that have evolved to camouflage creatures the authors consider how light affects an eye. Given there are a wide range of eye types this is a complex issue. We so often lapse into thinking the world is the way we see it, but it is not. Some other animals have better and some have poorer vision than we do. Yet they all survive in a competitive world.

The authors look at these types of questions and use research results to try to explain how colour affects the lives of earth's creatures. In a dozen chapters they discuss the initial camouflage through to detection by predators. They explore the lives of shrimp, grasshoppers, moths and butterflies, birds and mammals. They draw on work by Darwin, Wallace, Aristotle, Tinbergen and a host of others. Indeed they have 40 pages of references-nearly 15 percent of the book.

If you want to read a scientific thriller then this is your book. Do not expect that, like Hercule Poirot's cases, you will have a final answer on the last page. You may finish the book with more questions than when you started. That is the fun! This book opens your mind so you will never "See" the world the same way again.

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out what is going on in each plate and take your time – puzzle it out. The Preface and Introduction are must-read sections to fully understand the intentions of the authors and to get the most out of the guide.

The colour plates with the action shots are certainly the highlight of the guide. However, an important part of the *Crossley ID Guide* is the species accounts. These accounts are some of the best I've read. They are well written, informative, and packed with facts and figures – but not a boring or technical read. The opening paragraph is unlike anything I've read in a field guide: they are poetic at times or otherwise amazingly descriptive. For example, here is the opening for the Golden Eagle account: "Soaring high above a rim-rock canyon, a Golden Eagle has a commanding view of the surrounding terrain. Below, a roaring river snakes along the canyon bottom. Steep-sided cliffs offer ample substrate to build a nest, safe from any mammalian predator" (page 186). The accounts are worth reading for these creative narratives alone. The account header contains the common and Latin name of each covered species,

the four letter code (for example, GOEA for the Golden Eagle), and the page number for the colour plate layout.

Each account has labelled sub-sections that cover a specific aspect of the species; these include: Overview, Fight Style, Size and Shape, Plumage, Geographic Variation, Molt, Similar Species, Status and Distribution, Migration, and Vocalization. Each account has a colour distribution map which is helpful in determining the range of the species based on season (colour code key is on the very last page opposite the book cover and flap).

A bonus in helping beginning and advanced birders ID raptors are several mystery raptor plates. These mystery plates show several images of raptors in action and the reader is to figure out the correct ID based on what has been learned from the previous layouts. Answers are in the back of the book, but the reader should not look at the photo and then quickly see if they were correct! Doing this will not make you a better birder according to the authors – take your time – work out the image before checking the answer. Nothing is better than the real thing – looking at raptors in the field – but practising with this guide is the next best thing and will help enrich your experience in the field.

The *Crossley ID Guide: Raptors* does not cover nocturnal raptors, such as owls. At first I thought that the guide should have included them, but after some thought I can see why they were left out. The model

the guide uses is identifying raptors in flight (although perched photos are included). Owls typically do not fly around much during the day, unless they are flushed from their hiding spot (one exception is the Burrowing Owl, a diurnal species, but it doesn't really fly around much unless flushed or is foraging). The guide's success is teaching birders how to ID flying birds – birds that stay in flight long enough to make an ID or are high in the sky to allow prolonged observation. Owls do not soar like diurnal raptors and therefore another identification method will have to be developed to help in owl ID. I hope Crossley and others will produce an owl ID guide similar to this one. In addition, the authors include vultures and condors in their raptor guide, although they are not really raptors. They are included, I suppose, because they are raptor-like, that is, large diurnal birds that soar and often are mistaken for raptors. Including them in the guide will allow birders to compare and contrast them to raptors so firm identifications can be made in the field.

Overall, the guide offers a new way to study birds of prey and provides a renewed opportunity to enjoy our diurnal flying friends. The *Crossley ID Guide* series are a welcomed insight into the wonders of bird identification for seasoned birders and beginners alike.

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Ecology and Conservation of the Sirenia. Dugongs and Manatees

By Helene Marsh, Thomas J. O'Shea and John E. Reynolds III. 2011. *Conservation Biology* 18, Cambridge University Press, Cambridge, U.K. 521 pages, 65.00 USD, Paper.

There is no doubt that this is a scholarly treatise of the Dugongs and Manatees of the world. The authors have combed the scientific literature to compile an exhaustive summary of the evolutionary history, biology and conservation status and challenges of the Sirenia (Manatees and Dugongs) of the world. As such, it is of primary interest to Sirenian researchers and conservation biologists. However, there is still much here of interest to the general reader with a broad interest in natural history and conservation.

Four Sirenian species are distributed in warm, shallow tropical and subtropical waters around the globe today – the Dugong, West Indian Manatee, West African Manatee and Amazonian Manatee. This book delivers on the promise of its title. Every aspect of the ecology of present day Manatees and Dugongs, as well as other species from the evolutionary past, is detailed in a few very detailed and very comprehensive chapters, with a common and recurring focus on the conservation status and recovery potential of this imperilled order of marine mammals.

The biology of all four Sirenian species is covered in a thorough and well organized manner, covering extensive subject matter in broad chapters devoted to the

extinct Stellar's Sea Cow, evolution, feeding biology, behaviour and habitat use, life history and population dynamics, threats, conservation status, and conservation opportunities. For each topic, the available science is presented in a systematic and progressive manner for each of the four extant species, on occasion also referencing the Stellar's Sea Cow and ancestral Sirenians. Chapters end with an excellent summary comprising conclusions, implications for conservation and suggestions for future research. Surprisingly little is known about several aspects of Sirenian biology and ecology, and the authors do an excellent job of weaving together disparate research on the various Sirenian species into a cohesive, logical and comprehensive compilation. The subject is extremely well researched, and the reader gets the impression that virtually every published source dealing with Sirenian life history and conservation has been consulted in the writing of this treatise. Even interesting minor facts are included, such as the facts that both Dugongs and Manatees have died through impalement on the barbs of rays, that Manatees are less tolerant of approaching scuba divers than snorkellers, that there were past attempts to harness Manatees to clear vegetation-infested canals, and that

there is an international citizen science initiative (Seagrass-Watch) devoted to the monitoring of coastal seagrass communities (the principal forage of Sirenians).

The chapter on evolutionary history is the only one that is perhaps too detailed for the general reader. While the topic is thoroughly and exhaustively covered, the complexity of various prehistoric species – the fossil record, the intricacies of their evolution and phylogeny, their scientific names and places in the family tree, their DNA and genetic linkages, may be too much for all but the most dedicated and most interested reader. In contrast, one extremely fascinating and illuminating chapter is devoted to the natural history and modern-day extinction of the Stellar's Sea Cow, the only modern-day Sirenian that occurred in cool northern latitudes, and whose large size, slow movements, and incomplete diving behaviour made it extremely attractive as an easy food source for 18th century explorers and a prime and very vulnerable candidate for early extirpation.

Conservation challenges are many and varied. Beyond the general exposure to a fascinating and little known order of marine mammals that faces serious conservation challenges world-wide, by far the most interesting aspects of this book to general naturalists and non-marine mammal specialists are likely to be the sections on the current status, threats and conservation opportunities for all four species. There are many general conclusions and observations that are relevant to the conservation of many marine mammal species. The multiple threats from climate change are clear and worrisome globally, as are the effects of harvest and habitat degradation. Harvest, both intentional and incidental, is still an issue for all Sirenians except the Florida Manatee; in many areas of the globe a Manatee or Dugong carcass provides a substantial enhancement to family income or food. It is clear that there is much more research and management effort directed towards the West Indian Manatee, particularly in Florida, than for the other Sirenian species; yet even for that species, there are clearly significant knowledge gaps. Mortality from motorboat strikes remains a major mortality factor for Florida Manatees; even with some regulations on motorboat speed the authors note that Florida Manatee conservation is hampered by the "perceived right to travel by boat over publicly owned waters at unregulated speeds wherever they wish".

Beginning with the chapter on Threats, the tone of the book gradually and subtly shifts from the presentation of objective scientific data to that of science-based advocacy, for example challenging "slow-moving scientific and management communities". The authors challenge Sirenian managers and those managing other similarly-challenging species, pointing out that additional research and monitoring of Sirenian populations is often undertaken when it is urgent management action

that is required, simply because it is easier, and that sometimes the main threat to conservation is "our inability to solve conservation problems, even when the issues and potential mitigation options are identified proactively".

The book is well produced technically. It is well supplied with interesting and informative figures, photographs and tables portraying various aspects of Sirenian life history and ecology. Additionally, there are many insert boxes distributed throughout the text that provide interesting supplemental details on the general topic being discussed. There are only a few puzzling and less than ideal uses of figures and tables. The numerous black and white photographs are placed throughout the text, readily located immediately after their reference in the text. However a subset of colour photographs is also inserted in the centre of the book without any specific reference or rationale for why they are included, and duplicating only a small portion of the many black and white figures. While the photographs undoubtedly add value, they also provoke confusion as there is no hint to the reader or any apparent logic as to when there is a duplicate colour copy of the image that could be referred to, and they appear almost an afterthought. Another irksome detail pertains to the inset of multiple (14) small boxes over a span of 60 pages all pertaining to various threats to Sirenian populations as they were individually identified in the text. The first few boxes were very difficult to understand, as they show only a single bar for each species, with text indicating that the degree of shading reflects the severity of the threat. The meaning of the reference is only discerned after viewing several of these miniature charts, particularly as the bars in the first chart were only black and white. It would have been much clearer and much more useful to have compiled all of these threats and their degree of severity into a single comprehensive table. Another cumbersome use of the otherwise very informative inset boxes was a box (7.6) that asked several questions raised about the adequacy of warm-water refugia for Florida Manatees; a second box (7.7) two pages later repeated these same questions with very short answers; one inset box would have sufficed. But these are admittedly minor criticisms in an extremely well-written and well-researched book.

Ecology and Conservation of the Sirenia. Dugongs and Manatees is an obvious labour of love, and an encyclopaedic summary of research on four widely dispersed Sirenian species facing many different life history challenges and human threats throughout their range. It is also a call to action for difficult decisions and essential conservation actions, a call that will resonate with all conservation-minded readers.

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The Snakes of Ontario: Natural History, Distribution and Status

By Jeffrey C. Rowell. 2013. Art Bookbindery, Suite 5-1377 Border Street, Winnipeg, MB, Canada, R3H 0N1. 411 pages. \$55.00 CAD, Cloth.

Herpetology, the study of Amphibians and Reptiles (aka “herps”), has a somewhat dubious and decidedly brief history in Canada, undoubtedly because the country harbours fewer than 100 species of herps, with most of them shivering in shrinking relic enclaves hugging the US border. Canada has nevertheless had some illustrious herpetologists, but they have not produced much in the way of substantial books on their discipline. Most Canadian herp books have been slim, paperback field guides with pen and ink illustrations, coarse maps, and repetition of the same basic, even banal, descriptions of morphology and habitat. A recent exception was the entertaining “Snakebit” by Leslie Anthony, but that was more about ‘weird herpetologists’, an amusingly redundant term, than the beasts themselves. The weighty Canadian tomes devoted to other vertebrate taxa, like Peterson’s *Mammals of Eastern Canada*, and Banfield’s *Mammals of Canada*, or Taverner’s *Birds of Canada*, and Tozer’s *Birds of Algonquin Park* or Scott and Crossman’s magnificent *Freshwater Fishes of Canada* are not matched by herpetology. Even insects and flies have Stephen Marshall’s massive volumes to boast of. There are also numerous substantial, scholarly Canadian books on single species that are more substantial than any herp book. It is almost as though our depauperate herp biodiversity has convinced the herpetologists that there is no point to writing a grand synthesis. Of course, our herps also lack the charisma of polar bears or peregrines, the gourmet properties of ducks and salmon, and the sporting attractions of all the above. Trophy snapping turtles or ratsnakes decorate few game rooms, and herps have little impact on the GDP or global food supply. Snakes, frogs and their kin don’t need or deserve more than skinny paperbacks. Or, if one wishes to be cruel, one can imply that most herp enthusiasts aren’t terribly strong on reading and scholarly pursuits as much populating their dank basements with scaly, slimy pets to go with their tattoos and bad taste in apparel.

However, with this monumental work by Jeff Rowell, Canadian herpetology has made a huge leap forward. It is like going from the ‘Twitterverse’ to Margaret Atwood. *The Snakes of Ontario* is a massive 400-page effort, longer and heavier than most previous Canadian herpetology books combined. I feel utterly justified in saying that it is a book no serious Canadian herpetologist should be without. Remarkably, it only covers the 18 species and subspecies of snakes found in Ontario, much fewer than in a single county in Georgia as an American colleague once chortled to me, although twice as many as in any other province and more than the rest of Canada combined. Perhaps more interesting is that its author is not a herpetologist. His academic background, like that of Darwin, was geology,

and when he decided he didn’t want to excavate the northwest Territories for mining corporations, he turned to an even less herpetological discipline, computer science. Nevertheless, he tells us in the preface that he has always liked snakes, although he does not appear to be one of those collectors who frequent reptile “shows”, drooling over exotic mutants to house in his bedroom. In other words, he doesn’t appear to be one of those ‘weird herpetologists’ bent on collecting, trading, and breeding for show and tell sessions in trade-fairs at the local Legion or in the rear of motorcycle repair shops.

I have always felt that herpetologists often trail behind the other taxonomic specialists. Take conservation as a case in point. In the good old days, a vertebrate scientist would collect specimens of the taxa of interest, mammal skins, bird eggs, pickled fish, but by the time I started my academic career these practices were eschewed by ornithologists, and most mammalogists; small mammal trapping was still a joyful pursuit at the meetings. Ichthyologists still netted and hooked endless specimens, but they were focussed too on calculating MSY and creel counts, having become cognizant of the perils of overfishing. Herpetologists seemed immune to the idea that their quarry could be over-harvested or that they should exist free of formalin. Even today, ‘herpers’ rush out at lunch breaks at the SSAR meetings to grab some snakes and salamanders. This practice is slowly being abandoned, but the notion that their beloved subjects were disappearing came late to herpetology which still attracts the Indiana Jones crowd and those daredevils with southern or Aussie accents who populate the Outdoor Learning Network. Now, however, the paperback field guides lament declining frogs, and the beleaguered turtles (“7 of 8 Ontario species are at risk”). Rowell’s book will vault snakes into this sphere of concern as he makes it clear that Ontario’s snakes are at least as at risk as its frogs and turtles. Nevertheless, one gets the impression from Facebook babble that most herp people still think their subject consists of flipping logs and collecting anecdotes.

Rowell begins with a review of current ideas on taxonomy depicting cladograms (evolutionary relationships), starting at the broader level of all tetrapods, then going to narrower charts showing the more detailed phylogenies at the family and tribe levels of various Ontario snakes. Overall, he presents a clear summary of taxonomic issues, including the, in my opinion, vexing habit of herpetologists to fret over every ‘scientific’ and common name. I especially like the disagreements over the ‘scientific’ name of the Eastern Fox Snake. Whereas the common name has stayed consistent for more than a whole decade, the Latin binomial has changed faster than a chameleon’s colour, the genus

transforming from *Elaphe* to *Pantherophis*, to *Pituophis*, to *Mintonius* and back to *Pantherophis*, my favourite, in that same decade. This would be funny, but somehow many herpetologists take special joy in carefully following these changes as though they were keys to a special jargon that opens the sacred door to Alfred Romer's Cabinet of Wonders. Rowell follows this painful subject with a clear and concise summary of the evolutionary and biogeographical history of Ontario serpents. My favourite section in this part of the book is the well-illustrated discussion of the relationship between environment and distribution. I still remember being exposed to the concept of the effect of temperatures on distributional limits of Canadian reptiles in Bleakney's classic 1958 paper. Somehow, this brilliant insight has kept disappearing from the literature, but Rowell gives it a good boost here. This entire section makes thought provoking reading.

Rowell next presents a superb chapter tracking the history of snake study in Ontario, illustrated with portraits of the key players. We learn that one of the earliest Ontario herpetologists, the irascible Dr. Garnier, "dared to swear like a cattle driver and never went to church". This noble tradition remains a sacrosanct precept of the discipline to the present day. Even though much of Canadian herpetology tried to keep anecdotes at the forefront of the discipline, by mid 20th century, more serious research began to dominate with the redoubtable Sherman Bleakney, his talented protégée Francis Cook and the dedicated Craig Campbell, all still alive and sufficiently idiosyncratic to be affectionately deemed 'weird herpetologists'. Early work was associated largely with museums, but by the 1970's academic research on herps expanded to the universities and the literature widened to include numerous reports, peer reviewed papers and even a couple of multi-authored books on conservation. With Rowell's book, we begin a new era.

Next is a section on threats and conservation status. Here we get a somewhat truncated discussion of major threats, and a revealing chart of current COSEWIC/COSSARO status assessments showing that snakes in beloved Ontario are in dire straits. Indeed, one could look at the chart and conclude that snakes are doing worse than turtles. Fourteen of 20 are assessed as at risk, only 2 are not at risk (Northern Watersnake and Dekay's Brownsnake) and 4 others have not been assessed. These latter half dozen could easily be at risk, but we don't have the data to make defensible assessments. From my somewhat biased view, this section could have been more emphatic and provocative. This section ends, appropriately with some amusing old myths about snakes. This section could be endless. Just in the past year, I have been assured by a friend that she saw a "black snake" over 10 feet long (near Barrie) and a hotel manager who insisted that fox snakes could kill children. The chapter ends with a brief section on First Nations' views which seem no less bizarre than those of the rest of us.

The bulk of the book consists of accounts of each species. Each account is lavishly illustrated with colour photos, mostly by the author, of the beasts themselves. Where appropriate, there are photos of different colour phases and patterns (e.g., Eastern Hog-nosed Snake), drawings of unusual features, such as the oral apparatus of some species, and histograms of the distributions of intra-annual records by dates from the Ontario Herpetological Atlas. Each species also has coloured maps of historical and current distribution, photos of habitat and sometimes maps of relevant habitat features. Each species' account has 9 main sections following a pattern of similar to COSEWIC reports. Sections are; Physical Description, (with photos and some drawings), Nomenclature (herp people will like this), Taxonomy (more thrills), Status and Distribution (including Historical and Current Distribution, often broken down by region), Habitat, (including some photos and charts), Behaviour and Patterns of Activity, Diets and Feeding, Reproduction and Growth, and Predators. Chapter lengths range from 10 pages (Smooth Green-snake and Northern Ribbonsnake) to 32 pages (Massasauga), reflecting nicely which species have been looked at more and which have been neglected. I think it interesting that the most studied species are those that have been assessed Threatened or Endangered by COSEWIC. Those species that remain not assessed, not at risk, or Special Concern clearly have relatively limited data available, particularly on abundance, trends in abundance and impact of threats. Again, it is probably lack of data, not level of risk, that puts snakes in these more "positive" categories.

One of my more brilliant colleagues after perusing a copy of this book commented that it did not target an audience. I begged to differ. It targets everyone who has an interest in snakes, especially those whose interest goes beyond eating or displaying them. The Snakes of Ontario demonstrates, despite the paucity of species and herpetologists, that there is a rich, provincial history, luxuriously attested to by Rowell's bibliography of more than 2000 references. The cornucopia of references forms the source for his wide ranging text and plethora of coloured maps and figures. For the novice, there is a useful 5-page glossary including some cool herp terms such as opisthogyphus, key concepts like vicariance, and the inconvenient truth that there are at least 3 definitions of species. For the snake expert, there is a wealth of information that can form the basis of ideas and hypotheses for research.

This book is not, of course, one that you take into the field to identify snakes, but let's face it, there are fewer than 20 to identify so how hard can it be? You can take a pocket guide in the field, but I don't believe there are any current field guides that come even close to providing comparable pictures and information to assist in tricky identification.

So some careful reading beforehand and a good camera to take photos to compare with the book when you are at leisure after returning from the field can

confirm your identification. This book is a must for any serious herpetologist, but it should also appeal to a wide range of naturalists and biologists. I hate to call it a coffee-table book, but it would not be out of place there just as it should grace the serious biologist's desk or library shelf. I think the book is like a combination of James Harding's *Amphibians and Reptiles of the Great Lakes Region* and Harry Greene's 'Snakes: the Evolution of Mystery'. Snakes need lots of positive publicity. Anyone who reads Rowell's book will find snakes immensely more interesting than they will reading the treacly summaries found on those endlessly repetitive government sponsored conservation websites, because Rowell, like Greene, places his subjects in a broad context so that one sees them as a part of regional landscape and history. We often read that loss of this or that species or group of species will lead to ecological disaster, or similar Armageddon. I much prefer the

perspective that the potential loss of our snakes will not lead to ecological collapse, but will rob us of an fascinating element of our provincial natural history. I can't think of any recent book on our native fauna that promotes this perspective so well. Herpers and normal citizens all have their trove of stories that reflect the natural variety of our surroundings and society. When you read this book, you want to integrate its content with your own snake experiences, experiences that we all have. The *Snakes of Ontario* melds the herpetological, biological, and historical into a compelling picture of our relationship with other creatures that goes well beyond a single target audience of reptile lovers to the whole changing fabric of our culture. The target audience should be everyone.

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BOTANY

Common Mosses of the Northeast and Appalachians

By Karl B. McKnight, Joseph R. Rohrer, Kirstin McKnight Ward and Warren J. Perdrizet. 2013. Princeton University Press. 41 William Street, Princeton, NJ, USA, 08540-5237. 301 pages, 24.95 USD, Paper.

To my knowledge this guide, another in the line of Princeton University Press field guides, is the first field guide covering the mosses. This is fortunate because mosses are common but frequently under-appreciated by naturalists. The publication of a field guide helps to bring knowledge and recognition of little known organisms to popular attention and can lead to better information on distribution and abundance.

The arrangement of the guide is by growth form and leaf shape. These categories are colour-coded on the edges of the guide's pages to help in identification. There are keys that correspond to each of these features.

The book's claim is that you can identify any moss within the geographical area with a hand lens and spray bottle, and of course, the field guide. This claim is accurate although I would add an Xacto knife or razor blade to this in order to help separate plant parts for identification or collection. The guide provides some excellent instructions on how to examine moss and how to collect moss for a reference collection. This includes some instructions on how to make a paper folder to place a sample.

The geographical area covered by this guide includes much of southeastern Canada, New England, the Great Lakes states, and the Appalachian Mountains. The guide is also potentially useful in other parts of the upper Midwest. It covers an area of high moss diversity.

Each species account includes a colour photo of the moss and drawings of the stems, capsules, and leaves. There are also colour close-up photos of plant characteristics, descriptions of appearance, leaves and capsules. There is a description of the habitat and similar species that may be confused. Finally, there is a description of microscopic characteristics. A microscope is not essential to identify mosses in this guide, but having one is value-added to studying these plants.

This is an excellent easy to use guide that I hope will be in the knapsack, back pocket, or library of every naturalist. I predict this guide to become a popular addition to the naturalist's field guide collection and that it will enhance the appreciation and understanding of these underappreciated organisms.

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OTHER

More Than Birds: Adventurous Lives of North American Naturalists

By Val Shushkewich. 2013. Dundurn Press, 500-3 Church Street, Toronto, ON, Canada, M5E 1M2. 296 pages, 27.99 CAD. Paper.

This is a book about some people I know, some I know of and many who are part of ornithological history. It covers 22 naturalists, four of whom are still alive and well. Each person gets a compact biography of a dozen pages. This allows the author to capture the essence of a naturalist's life and give a sense of their contribution to ornithology.

I was one of a multitude of birders to go into the field with Murray Speirs. Even an hour with Murray was an enlightening experience that changed your perspective. My own resolution following a day with Murray was to take far better daily notes. Although I saw Doris Speirs many times I only went out with her once. This was an expedition to see an Ivory Gull that became an unforgettable Keystone-cops farce.

Bob Nero is a legend in the prairies. He spent much of his life promoting conservation with his partner Lady Grayl, a Great Grey Owl. When he introduced me to this lovely bird he insisted I tickle its tummy. I was amazed to see my index finger disappear into the thick layer of feathers. It was as memorable as Ruth's hospitality.

Although I never met Robert Bateman, I did spend time on a board with his brother Ross. From him I learned of Robert's change from an art teacher to a full-time professional.

The remaining 19 people are people I have known about for many years, some more intimately than others. For all these naturalists the author provides a good summary of their lives.

The early naturalists are represented by Alexander Wilson, John James Audubon and Thomas Nuttall. These amateurs became the founders of ornithology in North America. From humble beginnings these three men overcame major obstacles to bring North American birds to the world. It is hard to imagine Audubon giving dance lessons to finance his art or Nuttall living from hand to mouth as he worked on both plants and birds. Incidentally Nuttall's great bird book – *Manual of the Ornithology of the United States and Canada* – is available on line at <http://www.archive.org/stream/manualofornithol00nutt#page/124/mode/2up>. Audubon's monumental folio did bring him wealth before he died, but you will need more than \$10 million to buy a copy today.

The Smithsonian has had an enormous influence on natural science on this continent and has provided us with great scientists. These include Spencer Baird, Robert Kennicott and Robert Ridgway. All three were brilliant innovative men, each of whom made some special contributions to ornithology.

The next group of four includes the first two women who became famous as ornithologists. This was at a time when women were not always taken seriously and travel and exploration was tough going for everyone.

When I read the chapter on Jack Miner I wondered how he would handle Miner's controversial traits. His conservation philosophy was very selective. He believed God put birds on earth for man's control and use. With this religious viewpoint he considered non-monogamous and predatory birds (hawks, owls and crows) morally bad, and took measures to eliminate them. The author downplays this aspect of Miner's life. He also infers that Miner in North America was the first to band birds and this is incorrect (this technique had been introduced by Leon Cole some years earlier than Miner's first trial.)

For reasons I do not understand I knew little about James Henry Fleming until I read this book. He was a Canadian pioneer who gave his extensive collection to the Royal Ontario Museums of Zoology (now the ROM). He was also an influence on Canada's first professional ornithologist, Percy Taverner. This is a man I do know, having bought two of his three major books. Margaret Morse Nice was a legend when I arrived in Canada. This delightful lady showed us all the importance of patient, detailed study. Her studies on the Song Sparrow gave her justifiable fame that she used to promote bird conservation. Joseph Dewey Soper was a Canadian Arctic explorer and productive author. He opened our eyes to the magic of the Arctic, renowned for his studies on the Blue (Snow) Goose. Louise de Kiriline Lawrence survived the Russian Revolution to become first a Canadian nurse and then a naturalist. Her prolific writings were the backbone of the National Audubon Society magazine.

The author has chosen some of the key figures in Natural History in North America. His book would be wonderful to read on an aeroplane or at a cottage. It is written in a smooth flowing style that is effortless to read. Because each of the chapters is a complete story it is easy to pick up and put down, despite interruptions. I do have a few quibbles, apart from my comments on Miner's dark side. Some biographies end abruptly – most notably Audubon's. I would like to have seen Earl Godfrey added to the book. Overall it was fun to read and enlightening to be reminded of the tremendous contribution each of these people made to the study of wildlife in North America.

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Climate Change Biological and Human Aspects (Second Edition)

By Jonathan Cowie. 2013. Cambridge University Press, 32 Avenue of the Americas, New York, NY, USA, 10013-2473. 558 pages, 66.00 USD, Paper.

A bland academic text which when combined with the plethora of new books on this “hot” topic is more likely to contribute to climate change through deforestation required to print the book’s 558 pages than provide much needed practical solutions (though I would be the first to admit practical solutions to reigning in humans remain wishful thinking at best). The first four of eight chapters plough through earth’s climate of the past 4.6 billion years reviewing how we unravel past climates and reciting variation of key biotic and abiotic variables associated with the earth’s variable climate. Material that provides important context for the current human-driven climate anomaly, but, if biological and human aspects are the intended focus of the book far too much time is spent presenting material that is well documented in existing literature.

The remaining chapters presenting human and biological dimensions tend to be simplistic, for instance the “dust bowl” of the Midwest United States that occurred between 1934 to 1936 is attributed solely to drought, whereas a deeper understanding should consider complex socio-economic factors such as the expansion of mechanized farming, the Great Depression and concurrent falling prices for wheat which lead to desperation among farmers who embarked on massive expansion of unsustainable agricultural practices in an attempt to turn a profit from a larger harvest. Would there have been a dust bowl if the land cover was drought resistant native grasses and forbs?

Cycles of drought that are part of “normal” climate can be disastrous when human ambitions ignore the role of climate variation within the landscape; the Sahel is an example where traditional transhumance practices that used a wide-mesh “net” of animals was able to sustainably capture meagre resources and provide a secure “living food-store” which expanded and

contracted from year depending on the prevailing climate and availability of resources. When this was transformed by installing bore holes, sedentarization of the human population, large scale irrigation, and mechanized farming techniques the result was an initial success that happened to be combined with a pluvial period, followed by disaster, including great human suffering, during what was a “normal” drought period.

The take home lesson is, human well-being is intimately linked to past and present climates in complex social-political-economic-ecological relationships and while there are some examples of these presented in Cowie’s treatise, the magnitude of likely impacts given the current trajectory of climate change is not conveyed. The discussion of “extreme weather events” in three and half pages is more cautionary (i.e. statistically a single extreme weather event may be within the normal range of variability) than visionary. What is needed is a catalogue of recent social-economic-ecological costs of individual events such as have occurred in the past twelve months, rainstorms causing flooding and landslides in Brazil, tornadoes in Bangladesh, storm surge causing flooding in New York City, high wind event in Calgary, snow storms in Eastern Europe.

Human systems have adapted to operate within climate limits, as climate limits change there is a need to re-adapt human systems to the new climate world. Simply understanding the science of climate change will not, as the author suggests, be sufficient to drive the enormous social-political-economic change needed for future human well-being, not to mention the survival of the rest of life we share this planet with.

BRENT TEGLER

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Dinosaur Train

Produced by The Jim Henson Company and others. 2009-present. PBS Kids.

It may seem odd to review a children’s television series for a natural history journal. Television, after all, is often considered “the enemy” of getting kids outside to enjoy nature. It is even odder to review the biological accuracy of a series in which talking dinosaurs travel through time on a train. However, given the popularity of the series *Dinosaur Train* and its influence on children’s understanding of palaeontology and appreciation for nature in general, it is appropriate to critically evaluate the series here.

About the show

Dinosaur Train is an animated children’s series produced by The Jim Henson Company (of Muppets fame)

and others, and broadcast on the PBS TV station. It has completed two seasons since its inception in 2009, consisting of 66 episodes at the time of writing. My review is based on Season One, which I watched with my three year old son over the span of several months.

Each 30 minute episode consists of two 11-minute stories involving a family of *Pteranodon* (large flying reptiles), with brief live action segments hosted by paleontologist “Dr. Scott” Sampson in which he discusses the biology of dinosaurs featured in the episode. The *Pteranodon* family consists of two parents, three children with distinct personalities, and adopted son Buddy the *Tyrannosaurus rex* (who, before hatching,

somehow ended up in the *Pteranodon* nest). Stories generally follow a pattern of Buddy and other members of the family being curious about the biology of other dinosaur, or non-dinosaur, species. They then travel on the Dinosaur Train, through a time tunnel, to the region and time period in which the species in question lived. They then play and sing with the species while finding out about its biology. For example, they play music with young Hadrosauridae who produce loud calls through their head crests, which is the leading explanation of the function of these dinosaurs' crests. The dinosaurs then go home and discuss what they have learned. Finally, Dr. Scott tells the viewer what paleontologists know about the episode's species, and how they compare to species alive today.

Biological accuracy

Aside from the obvious (we have not yet found evidence that dinosaurs built trains or time tunnels), the show is very accurate biologically. Not just accurate, in fact, but cutting-edge. Dr. Scott, the host and primary scientific consultant for Dinosaur Train, is not only a real paleontologist but in fact he is a big-shot young paleontologist. He is Vice President of Research and Collections at the Denver Museum of Nature and Science, has published paleontological research in leading journals (e.g., *Nature* and *Science*), and recently authored a book on dinosaur ecosystems (Sampson 2009). He also happens to be Canadian.

Adults, even those passionate about biology such as readers of *The Canadian Field-Naturalist*, will learn a great deal about dinosaurs from this cartoon. Dinosaurs you did not learn of as a child since they were undiscovered or poorly known scientifically, such as the terrifying giant carnivore *Spinosaurus*, are given prominence. Dinosaurs you did learn of as a child are shown with current nomenclature (e.g., *Brontosaurus* is now *Apatosaurus*) and behaviour reflecting modern interpretations of fossil evidence (e.g., dinosaurs were likely more lively than the lethargic tail-draggers we learned about years ago). Watching the show alongside your children will allow you to keep up with your children's knowledge of dinosaur biology.

In the interest of simplifying stories, Dinosaur Train sometimes takes liberties with accuracy. For example, one episode portrays *Lesothosaurus* as camouflaged, inspiring discussion of the reasons for animal camouflage. While modern techniques allow insights into the colour of some dinosaur feathers (Li et al. 2012), we cannot determine whether species were camouflaged because we do not know their microhabitats. These liberties are understandable from a story-telling perspective, and Dr. Scott often tells the viewer when the show takes these liberties.

In the interest of not scaring children, ferocious dinosaurs are also portrayed in a more friendly light. Giant carnivores dance and play with smaller herbivores, rather than ripping them to bloody shreds. At first I was disappointed with this puppyfication of dinosaurs, but after seeing how scared my son was of even a gen-

tle version of *Spinosaurus*, and considering the sleep I was saving from him having fewer nightmares, I am now satisfied the accuracy sacrificed by having gentle dinosaurs is worthwhile. Dinosaur Train does discuss what each species ate; it just does not show carnivores hunting prey.

I did find two minor inaccuracies, neither concerning dinosaurs. In one episode a grasshopper is shown stridulating its wings to produce sounds (grasshoppers actually produce sounds from leg stridulations – crickets rub their wings), and a dragonfly is shown eating leaves (dragonflies are carnivorous). These inaccuracies are surprising for how basic they are, and how accurate the show generally is, but they are very minor.

The show's message

First, considering the non-biology messaging of the show, Dinosaur Train models appropriate behaviour for children. The characters are polite, curious, enthusiastic, and generally cooperate with each other. Children's shows often show characters engaging in bad behaviour (e.g., characters being unkind) before learning not to do those behaviours. Young children, however, have difficulty connecting characters' early behaviours to consequences and resolutions later in the show, and often engage in the types of bad behaviours they watch on television (Ostrov et al. 2013). Dinosaur Train provides a welcome relief to parents keen to avoid shows with bratty characters.

When it comes to biology-related messages, I know of no other kids' show that comes close to Dinosaur Train for promoting curiosity and exploration of our natural world. Many episodes involve the show's characters finding something unusual, developing hypotheses (yes, they even call them hypotheses!) about the finding, then exploring to find out more about it. Along the way, other biology-related themes are explored both subtly and explicitly. For example, an introvert character on the show (Don) keeps a collection of interesting objects such as feathers and bones. In one of Dr. Scott's segments he makes the link between Don's collection and the importance of museum collections to research. In sum, Dinosaur Train promotes naturalist-friendly messages at the small scale of individual discoveries, and at the broad scale of the joy of exploration that permeates the show.

Does the show's message trump its medium?

The very medium of TV poses a conundrum – is it possible for a children's TV show, even one with great naturalist messaging, to benefit children's naturalist tendencies more than it harms them? Some naturalists consider TV to be the enemy, responsible for keeping kids indoors instead of outside exploring nature (Pergams and Zaradic 2006). In my opinion, the merits of Dinosaur Train should not be compared against the merits of playing outside; this is a false dichotomy. Most parents are going to let their kids watch TV. Given this reality, I think it is appropriate for Dinosaur Train to be compared to other children's TV shows. In

such a comparison, *Dinosaur Train* comes out triumphant, being far superior in its biology-related and non-biology-related messaging than most other children's shows in my experience. The *Dinosaur Train* parents' website (www.pbs.org/parents/dinosaurtrain/) also provides ideas for parents and teachers on how to link episodes' main messages to children's activities (e.g., making a bedsheet cloak for the camouflage episode). Further, the *Dinosaur Train* Nature Trackers Club (www.pbs.org/parents/dinosaurtrain/more-dinosaur-train-fun/nature-trackers-club/) encourages kids to complete nature challenges outdoors (e.g., track animal footprints, organize a neighbourhood cleanup). *Dinosaur Train* thus attempts, successfully in my opinion, to be a TV show that encourages kids to turn off the TV.

In sum, *Dinosaur Train* is biologically accurate, contains positive role models, and encourages kids to "get outside, get into nature, and make your own discoveries," as Dr. Scott says as his signature sign-off at the end of every episode. I recommend it over any other children's TV series I have seen. Two examples illustrate the power of this show. First, my son has started a nature collection, consisting of some rocks and clam

shells he's found, inspired by Don's collection. Second, I have read Dr. Scott's *Dinosaur Odyssey* and various dinosaur blogs, inspired in part by the paleontology I learned about from *Dinosaur Train*. Any children's show that encourages kids and even adults to discover more about nature is a good thing in my opinion.

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Protection of the Three Poles

By Falk Huettmann (ed.). 2012. Springer Publishing Company, 11 West 42nd Street, New York, NY, USA, 10036. 337 pages, 149.00 USD, Cloth.

Hardly a day goes by without seeing or hearing some mention of climate change. Satellite images of ice shelves disintegrating, photographs of extreme flooding and drought, and predictions of species extinctions at the Poles are alarming and should cause us to evaluate human behavior in the context of unrestrained economic growth. But, do they, and is it already too late? It might be. In fact, the Foreword of this book includes a prospective "Epitaph for the Poles." In the pages that follow, the book's 31 contributors provide such a bleak assessment of the current state of polar protection that the reader might well decide to seek solace on the nearest barstool or pew. The Introduction, written by the Editor, is a no-holds-barred exposé of the climate change crisis that is both entertaining and unsettling (and depressing). He reviews how rapidly changing abiotic and biotic conditions at the Three Poles – Arctic, Antarctica, and Hindu Kush-Himalaya – warn of a broken global system and reflect the predictable outcome of an "aggressive and inappropriate business model" that willfully ignores concepts of carrying capacity and sustainability. Sustainable development and sustainable growth are fraudulent ideas whose legitimacy must be questioned and whose practice must be stopped. All groups bear responsibility for climate change, some more than others, as he condemns scientists, governments, NGOs, international corporations, and the media. Natural resource management, as currently implemented by individuals, groups, and insti-

tutions, is failing and a new science, one with sustainability on its main agenda, is needed. He hopes the book will provoke the discussion necessary to achieve global welfare.

After this blistering Introduction, I was surprised to find the 11 content chapters somewhat traditional in scope and relatively uninspiring. The first is an overview of the International Polar Year of 2007-2008, focusing on the benefits and challenges faced in realizing what was to be one hallmark of the effort – freely accessible data (we learn later that only 35% of participants fulfilled this commitment). The next two chapters are Antarctica case studies: the first addresses human exploitation of the Antarctic Toothfish in the Ross Sea and the second evaluates how the Madrid Protocol aspires to protect wilderness and aesthetic values of the continent. Two case studies on the Hindu Kush-Himalaya follow, one analyzes the importance of the Third Pole and how it should be protected, and the other reviews the Himalayan Uplands plant database and its accessibility and usefulness for conservation. The next five chapters, the largest section of the book, are devoted to the Arctic. Two chapters cover marine mammal conservation in Russia, one based on community interest and involvement (bottom up) and the other taking the more customary approach linking government policy and actions (top down). The next two chapters on Arctic waterbirds and seabirds discuss the daunting challenges associated with conservation

at a truly global scale, considering long-distance migrations, circumpolar distributions, and an increasing industrial presence. The final content chapter warns of potential shifts in disease distributions and their consequences as a result of climate change.

The conclusion, immodestly titled "Yet Another, But This Time Realistic, Polar Synthesis, Meta-analysis, and Outlook", is nearly twice as long as any other chapter. In it Huettmann repeats much of the criticism leveled in the Introduction, recounts specific failures in polar conservation, identifies the organizations and institutions bearing responsibility, and calls for implementation of the environmental ethics of Aldo Leopold and others. He then lists the actions individuals should take to affect change and the ways science should be restructured to address the climate crisis. Both lists merely repeat what you would find in standard conservation texts.

Huettmann engages the reader while he disassembles nearly everyone and everything related to conservation, but the book is supposed to be about the three poles and I would have liked to see less of his writing (89 of the total 337 pages) and another two or three content chapters. In fact, given the criticism he levels at unsustainable economic growth, it seems a major shortcoming that a chapter on environmental economics is not included. I think field naturalists will appreciate much of this book, particularly the chapters on

protecting wilderness values, mining plant databases, and protecting arctic birds. For an edited volume, the writing across chapters is remarkably consistent, yet I found the mixture of black and white figures and colour figures within chapters somewhat distracting. Moreover, some figures were of poor quality (6.2, 6.5) or completely useless given the complexity of the legend (e.g., Chapter 10 bird distribution maps, Textbook 1 in Chapter 12). The book is filled with dozens of internet URLs – I tested 10 and eight worked.

Finally, are there ideas or methods in this book that will help us achieve what Huettmann hopes is a "truly global sustainability?" Unfortunately, I think not. Despite his statement that the book and contributors are all about the "best possible solutions and smoothest possible transitions", most of the chapters outline distressingly commonplace problems (over exploitation, weak enforcement of protected areas, poor outlook) and offer traditional recommendations (a need for more data, more funding, and greater coordination among conservationists and organizations). All proceeds of the book are directed toward sustaining a Fellowship in the Protection of the Three Poles. Sadly, I think an Epitaph for the Poles may well be written by one of those Fellows in 50 years or so.

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned

Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros, AUD Australian Dollars.

ZOOLOGY

Tracks and Signs of the Animals and Birds of Britain and Europe. By Lars-Henrik Olsen. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 274 pages, 29.95 USD, Paper.

* **Concealing Coloration in Animals.** By Judy Diamond and Alan B. Bond. 2013. Belknap Press-Harvard University Press, 79 Garden Street, Cambridge, MA, USA, 02138. 288 pages, 29.95 USD, Cloth.

* **Odd Couples: Extraordinary Differences between the Sexes in the Animal Kingdom.** By Daphne J. Fairbairn. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 312 pages, 27.95 USD, Cloth.

Wildlife of Australia. By Iain Campbell and Sam Woods. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 288 pages, 19.95 USD.

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News and Comment

Can we Create Alvars or Fully Restore those Damaged?

PAUL M. CATLING

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Catling, Paul M. 2013. Can we create alvars or fully restore those damaged? *Canadian Field-Naturalist* 127(1): 97–101.

A brief survey of the literature indicates that there is no scientific basis for the assumption that a self-sustaining and fully diverse alvar ecosystem can be created or fully repaired following serious damage. Consequently it is much better to protect an existing alvar than to accept promised creation elsewhere, or full repair, as a justification for allowing damage due to human activities. Although conservation may be well served by establishing some alvar species *ex situ* in partially restored areas, at present the best way of protecting alvar diversity is by protecting alvars, through a well-planned system of protected natural sites of high quality.

Key Words: alvar, protection, restoration, quarry, rehabilitation, ecological integrity, Great Lakes region, Ontario.

Alvars are naturally more or less open areas of shallow soil over essentially flat limestone or marble rock with a cover of herbs and shrubs with trees absent or not forming a continuous canopy. They are a very restricted habitat and include rare and restricted flora and fauna. Ontario includes more than three quarters of the imperilled alvar ecosystems in the Great Lakes region (Brownell & Riley 2000, Catling and Brownell 1995). Many of the Ontario sites have been partly destroyed and damaged by permanent development or temporary use for construction on adjacent lands (Table 1, Catling et al. (2012) for examples of damage). Some developers have suggested that disturbance may be condoned because damaged sites can be fixed and/or disruption compensated for by creation of a new alvar elsewhere. The “fix” proposed may involve a mitigation plan. One proposal to develop an alvar and fix damage presently under consideration includes the following statements: “New alvar will be created ... For all alvar habitat disturbed during construction, re-vegetation to pre-construction conditions will occur as soon as possible after construction. ... if natural regeneration is unlikely to occur, ... re-vegetation through transplanting from established alvar communities ... or seeding ...” The likelihood of any of this restoration or mitigation occurring with a satisfactory result is low in light of recent literature and policy of the Canadian Botanical Association.

The question of whether or not creating or fixing is possible is an important one for alvar conservation because there is still much conservation work to be done on this very unusual and biodiversity-rich ecosystem and this work should have a strong scientific base to continue. Currently there is interest in updating the conservation targets for alvars in a new international protective effort that would extend the international alvar initiative of 1999 (Reschke et al. 1999). Also the very

significant contributions to protection of alvars in the Great Lakes Region have been made on the basis of “ecological integrity”, meaning that the least damaged and most complete sites were prioritized for protection. It is anticipated that a similar process will follow in the future.

A Summary of Alvar Restoration and Mitigation

(1) Bakker et al. (2007)

The title of this article suggests that alvar plants appear to be spontaneously colonizing old fields, but the abstract clearly indicates the limitations: “A group of alvar species had re-established after 20 years, but others did not re-establish even after 50 years of abandonment, although they are present in the local species pool. We found no evidence of dispersal as a constraint for re-establishment.” If in this study dispersal did not limit colonization of abandoned arable land there must have been other constraints, – possibly the changed condition of the soil, seed predation, or competition. Failure of a fully functional alvar community to establish over 50 years in an area surrounded by alvar indicates that these ecosystems do not automatically re-develop naturally. Further, it seems improbable that seeding would aid restoration.

(2) Lundholm and Richardson (1999)

The authors argue that limestone quarries must be used to conserve alvar biodiversity because there are not enough protected alvar sites. However, they provide no evidence that quarries can really do the job.

(3) Richardson et al. (2010)

Alvars are regarded by these authors as a “degraded state analogue” for quarry bottoms. This suggests

TABLE 1. Alvares usually benefit from natural events such as fire, drought and flooding. They do not benefit from unnatural disturbances such as development which may include the activities listed below (from Catling et al. 2012, personal observation and other sources). Most of these activities can be influential on-site and when occurring near to a site.

Type of activity/stress	Impact
(1) Building roads and structures on top of vegetation communities.	Complete and immediate destruction of flora and fauna.
(2) Driving over vegetation with heavy equipment in temporary storage and laydown areas.	Flora and fauna is crushed and the damage may range from complete destruction to limited and incomplete recovery.
(3) Building of crane pads and other temporary construction facilities	Complete destruction to serious damage and loss of native species diversity due to crushing and alteration of substrate conditions.
(4) Excessive foot traffic	Complete destruction to serious loss of native species diversity due to trampling.
(5) Introduction of nutrients from blowing soil, runoff, misinformed direct soil improvement practices, etc., to communities that require nutrient-poor conditions.	Competition with species that are promoted by higher nutrients and/or non-adapted abnormal growth leading to a modified community composition or elimination of particular community types .
(6) Contamination of substrate with fill, wash off of lubricants, and spillage.	Complete destruction due to serious spills to localized damage and diversity loss in a changed ecosystem.
(7) Changes in hydrology due to roads, ditching, compaction, ruts, and cable trenches, all leading to excess flooding in some areas and excess drainage in others.	Complete destruction of flora and fauna to seriously altered communities. A very delicate balance of extent and timing of water flow is essential to maintenance of natural alvar communities and it may include ground water, rain dispersion, sheet flow and temporary ponding over flat rock.
(8) Transport of contaminants over extensive areas by ground water and/or surface water flow during flooding.	Loss of native species diversity and alteration of communities.
(9) Introduction of invasive alien species with mud caked on the underside of construction equipment, in tire treads, with fill, or by natural processes.	Any disturbance is likely to increase the presence of invasive species and once present, elimination may not be possible and control may require extensive management making the loss of native diversity a certainty.

that some degree of restoration to alvar-like vegetation may be possible. Establishment of 18 alvar species seeded on a quarry floor was analyzed after three growing seasons and suggested strong dispersal limitation and weak microsite limitation for alvar species. Relatively rich species assemblages including some alvar components were developed, but experimentally seeded plots had only half the richness of alvar species as natural alvars and half the cover of vascular plants (Figure 4).

Richardson et al. (2010) provide evidence suggesting that targeting alvar assemblages in developing vegetation cover can promote efficient site colonization and *ex situ* biodiversity conservation. However, it is a skip, a hop and a jump (and a long hike) from here to saying that their data signifies that an alvar can be repaired or created. This is because: (1) Some of the alvar plants seeded in the experiment did not establish, others established to a very limited degree, and still others did not produce flowers and fruit enabling survival into the future; (2) Alvares may depend upon longer-term overall conditions as well as short-term annual conditions. For example, the severe drought that occurs on average once every 40–60 years that sets suc-

cession back may be necessary for the perpetuation of alvar communities. If so, observations made after a few average years may not be very informative; (3) Relationships between plants and other biota, (pollinators, consumers, predators of consumers, microbes, etc.) may be crucial to success of alvar plant communities, and these interactions are so complex that they probably cannot be recognized, let alone duplicated, in attempts to reconstruct.

The Richardson et al. (2010) experiment thus, while it produced valuable plant cover by seeding, did not include enough alvar species or biomass, continue for long enough, nor consider interactions and processes sufficiently to evaluate the possibility of repair or creation of a self-sustaining alvar plant community or an alvar ecosystem.

(4) Savanta Inc. (2008)

There are a number of articles such as this one available on the web concerning “aggregate rehabilitation” or treating land from which aggregate has been extracted to increase the utility of the land or to improve its condition. Some of these reports feature alvars, and sometimes important alvar species are conserved. How-

ever, these efforts have not produced the equivalent of a naturally-occurring alvar plant community or alvar ecosystem.

(5) Tomlinson et al. (2008)

This article projects that conditions on the floors of abandoned limestone quarries are similar to those on alvars and some of the species that are found on alvars also occur on abandoned quarry floors. Although observations were not new (see text box), it was of interest because it suggested that alvars could be used as a model, or analogue, for efficiently greening quarries and simultaneously protecting some rare and at-risk alvar species (extended by Richardson et al. 2010). Using artificial (built) landscapes for species conservation is a great improvement over filling a quarry with fertilized soil and planting it with alien Crested Wheatgrass! However, it is a mistake to conclude that fully-functioning and self-perpetuating alvar plant communities have been developed on a quarry floor.

The work of Tomlinson et al. (2008) was not designed to compare alvar and quarry floor vegetation; otherwise it would have used information such as cover, fruiting condition, number of individuals and biodiversity measures instead of just presence or absence. Nevertheless, the paper does indicate that alvars are biologically quite different from quarry floors: (1) Figure 1a shows all the alvar samples on the left side with almost no overlap between these and quarry samples; (2) In Figure 2c there are two major groups of species, the one with few exotics evidently represents the alvars. On quarry floors, 40% of the plant species recorded are exotics compared to only 7% of those on natural alvars; (3) "Characteristic alvar species" constitute 12% of the species found on quarry floors but usually 25-50% of species on alvars. However, rare and restricted species may also be important alvar indicators; (4) The authors note that the factors preventing quarry communities from resembling alvar communities even more closely than they do are at present uncertain – a noteworthy point!

(6) Solandz (2011)

This paper is one of a number reflecting on results from some of the peer-reviewed papers above. It also reports on studies aimed at establishment of alvar mosses on quarry floors. Like other studies, this review does not claim that alvar plant communities or alvar ecosystems equivalent to those of natural alvars have been produced.

To summarize, based on all recent papers mentioned above, the fact that some alvar plants may re-establish on abandoned arable land, and that with monitoring and gardening some can be grown on a quarry floor, at least for a short period, is good news. However, there is no case of a self-sustaining alvar ecosystem complete with all of its biodiversity and all of its ecological func-

tions being destroyed or seriously damaged and then completely repaired or created.

Policy of a national organization

Restoration, repair and the various methodologies involved, including transplanting and seeding, are useful and helpful to conservation in general, but the concept of restoration can be destructive if its conservation value is overstated. It is misleading to promise that mitigation will prevent irreversible damage, or resolve preservation versus development conflicts.

It was in 1985 that the Conservation Committee of the Canadian Botanical Association (CBA) advised against the development of a quarry on the Oriskany Sandstone Outcrop, an area of unusual geology, flora and fauna in southwestern Ontario. Aggregate extractors suggested that after they had removed all the rock, they would replace the flora exactly as it was by transplanting it to the limestone quarry floor. This assertion demonstrated poor biological understanding. The committee considered it impossible to restore what would be destroyed, either nearby or in the hole left behind, in part because growing conditions would not be the same. The CBA Conservation Committee then developed a "Position paper on transplantation as a means of preservation" (CBA 1986, 1991). This document reads in part: "Attempts have been made to recreate natural ecosystems through transplantation and seeding. Despite considerable expense, development of sophisticated techniques, and passage of time which might have allowed for establishment, such attempts can only be judged as partially successful."

The Canadian Botanical Association had a number of reasons for its position, which are elaborated on its website (Canadian Botanical Association 2013, Fahselt 2004, 2007). Many concerns related to the ecosystem as a whole, but it was also felt that, unlike *in situ* reproduction in the natural habitat, transplanting and seeding offered little protection in the long term. Morton (1982) supported this view, and Keddy (1983) wrote: "It is extremely difficult to demonstrate scientifically that transplanting will succeed." Many similar concerns have been expressed recently; for example, Lusby (1996) stated: "It is stressed that translocation experiments must be regarded as horticultural operations with a full and flexible aftercare programme to provide a reasonable chance of successful plant establishment".

Restoration – what does it mean?

"Restoration" does not necessarily mean putting an ecosystem or a community back just the way it was, and the assertion that "we can restore it" can have a variety of meanings. The Society for Ecological Restoration (<http://www.ser.org/resources>) defines ecological restoration as an "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability." Importantly

it “accelerates” but does not necessarily “complete.” Wikipedia (https://en.wikipedia.org/wiki/Restoration_ecology) notes that: “restoration ecology assumes that environmental degradation and population decline are to some extent, reversible processes. Therefore, targeted human intervention is used to promote habitat, biodiversity recovery and associated gains. This does not provide, however, an excuse for converting extremely valuable “pristine” habitat into other uses.” The wording: “to some extent reversible” is important. The alert to providing an excuse is also noteworthy. Operationally, restoration often means putting some of the species back, or allowing an ecosystem to partially recover on its own (Catling & King 2007) or with one time manipulation (Catling & Kostiuk 2010), or with continuing management. See also Bradshaw (1997), Hilderbrand et al. (2005) and Young (2000) for more information. Although it might be expedient for developers to regard it as an acceptable substitute or a complete “fix”, it is not, nor is it thought of that way by its proponents and performers.

The Lakeside Daisy Preserve: the Case of a great conservation effort but not a reconstruction

A quarry floor on the Marblehead Peninsula of Ohio became the last chance for the Great Lakes endemic Lakeside Daisy (*Tetraneuris herbacea*, Catling and Brownell 1995) in the state in the late 1980s. It was protected and became the Lakeside Daisy Preserve. This very worthwhile project protected a handful of extremely rare alvar plants that were nowhere else in Ohio and nowhere else in the United States. The two women responsible for the protection of this site received the Ohio Conservation Achievement Award in 1989, and it was well deserved. More recently the Lakeside Daisy has been established at other sites in northern Ohio, which may help to ensure the survival of the self-incompatible Ohio population.

This early use of a quarry to conserve alvar vegetation was a major achievement. However, it did not reconstruct the alvar ecosystem that was destroyed on the adjacent plateau, a few small remnants of which still existed when I visited the site in 1989. Seeding, transplanting and especially the continuing control of woody vegetation (Red Cedar, Dogwood, Cottonwood) is necessary to this day. The restoration of alvar, although an intense effort, has been partial. No subsequent establishment of alvar plants in quarry bottoms in the Great Lakes region has created an alvar ecosystem.

Integrity and excuses

If damaged alvars cannot be “fixed”, we should not accept the promise of a “fix” or a “creation” as an explanation (or excuse) for destruction. The primary conservation goal should be ecological integrity, meaning that “the structure, composition and function of the ecosystem are minimally impaired by stresses from human activity; natural ecological processes are intact

and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem’s biodiversity is ensured” (British Columbia Parks Legacy Panel 1999). Putting it most simply, the conservation objective should be “wholeness” of the natural environment. All we have to date as indications of our capability to create or fix damaged alvars is short-term establishment of a dozen vascular plant species, – one dozen out of hundreds of species in many taxonomic and functional groups. Given a choice, it is much more realistic to protect an existing alvar than to expect creation elsewhere or full repair. Since full restoration is not possible, environmental assessments and development permitting processes should indicate this clearly in the documentation.

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Sheila McKay-Kuja and Brenda Kostiuk provided useful information. Jennifer Windus provided details on the protection of alvar flora in quarries on the Marblehead Peninsula of Ohio. Dianne Fahselt assisted with writing.

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Outstanding Service from Associate Editors

One of the strengths of *The Canadian Field-Naturalist* and its predecessors tracing back to 1880 has been the participation of many long-serving volunteer reviewers, publication committee members, and associate editors. It is always with regret when one of these decides to step down.

This year we are losing formal association with two outstanding Associate Editors.

One is among the longest-serving of the Associate Editors over the publications history, Dr. Anthony (Tony) J. Erskine. Tony has served 38 years (1975–2012), nearly matching or surpassing his ornithological long-term predecessors, Earl Godfrey 41 years (1947–1975, 1990–2002) and Percy A. Taverner 32 years (1911 to 1942). Tony drew on a lifetime of field ornithology as a Research Scientist with the Canadian Wildlife Service from British Columbia to the Maritimes. For much of Tony's tenure, bird manuscript submissions were more numerous than those in any other field, and he often reviewed 25 or more manuscripts per year. He always submitted not only comprehensive and perceptive reviews with detailed suggestions for improvement or detailed of rejection, but also a separate note discussing the merits or defects for guidance of the editor. In the pre-computer era Tony's reviews

often were returned faster by Canada post than those of his younger colleagues who later had the supposed advantage of e-mail).

Due to the pressures of his current research commitments, also stepping down is Dr. Bob Anderson, M.Sc. Carleton University, Ph.D. University of Alberta, Post-Doctoral at Texas A. & M. and Research Scientist with the Canadian Museum of Nature with a special interest in weevils. Bob has served as Associate Editor for entomology since 2001. Although fewer manuscripts, two to seven a year, have been received for insects, this group is so diverse that an Associate Editor of entomology must have a good knowledge of active research in the field. Bob handily fulfilled this role, and we are indebted to him for his essential contribution.

The Canadian Field-Naturalist is indebted to Tony and Bob for their wholehearted support as associates and may occasionally still call on them for advice on future submissions.

The Canadian Field-Naturalist is grateful to the following individuals who have accepted the position of Associate Editor over the past two years: Jennifer Foote, Anthony J. Gaston, Tom Jung, Claude Renaud, Jeffery Saarela, and David Seburn.

Upcoming Meetings & Workshops

Northeast Partners in Amphibian and Reptile Conservation Meeting 2013

The 14th annual meeting of the Northeast Partners in Amphibian and Reptile Conservation (NEPARC) to be held 24–26 July 2013 at the New Jersey School of Conservation in Branchville, NJ. NEPARC is an active, diverse, and inclusive partnership dedicated to the conservation of amphibians and reptiles and their habitats throughout northeastern North America. More information is available at <http://www.northeastparc.org/meetings/index.htm>.

Botany 2013 Meeting

The annual Botany conference to be held 27–31 July 2013 at the Riverside Hilton in New Orleans, LA. This annual meeting is a multiple scientific society conference (American Bryological and Lichenological Society; American Society of Plant Taxonomists; Botanical Society of America; American Fern Society; International Association of Plant Taxonomists) serving over 6000 plant scientists whose research and practice span the globe. Registration is currently open. More information is available at <http://www.2013.botanyconference.org/>.

Ecological Society of America Meeting 2013

The 98th annual meeting of the Ecological Society of America to be held 4–9 Aug 2013 at the Minneapolis Convention Center in Minneapolis, MN. The meeting will look to the past as guidance in understanding and predicting future trends in ecosystem dynamics and services. Registration is currently open. More information is available at www.esa.org/minneapolis/index.php.

Society of Canadian Ornithologists – Société des ornithologistes du Canada Meeting 2013

The 32nd annual general meeting of the Society of Canadian Ornithologists – Société des ornithologistes du Canada to be held 12–14 Aug 2013 at the University of Manitoba in Winnipeg, MB. More information is available at <http://www.sco-soc.ca/meetings.html>.

American Ornithologists' Union/Cooper Ornithological Society Meeting 2013

The American Ornithologists' Union (131st Stated Meeting) and the Cooper Ornithological Society (83rd

Annual Meeting) joint meeting to be held 13–17 Aug 2013 at the Field Museum of Natural History in Chicago, IL. Registration is now open. More information is available at <http://fieldmuseum.org/explore/aoucos-2013/american-ornithologists%E2%80%99unioncooper-ornithological-society-2013>.

Raptor Workshop: Introduction to Raptor Field Techniques

Raptor Services, LLC presents 5-day workshops to be held in Stevens Point, Wisconsin by Eugene Jacobs of the Linwood Springs Research Station. This introductory level field course is designed to instruct students in a full-range of field techniques used in the study of raptors. Receive first-hand experience working with: live raptors, capturing, handling, banding techniques, broadcast call surveys, tree climbing, rappelling, blood sampling and more. Fall Sessions: 26–30 Aug, 16–20 Sep, and 7–11 Oct 2013. Cost is \$435 and space is limited (6–8 students per workshop). More information is available at www.RaptorResearch.com.

Erratum The Canadian Field-Naturalist 126(4)

In response to the review of *Contributions to the History of Herpetology*. CFN 126(3): 344–345, the book's editor Kraig Adler pointed out (personal communication to FRC 12 May 2013): "Only one small correction. Mrs. Martof used a kitchen knife, not a gun. She told the police she slipped while cutting some pizza. But Bernie was stabbed up under his rib cage several times!"

Erratum The Canadian Field-Naturalist

It has come to our attention that sections of many of the book reviews by Li Dezhi and Qin Aili were copied from sources without attribution. The journal and the authors apologize for this oversight.

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COVER: Prairie Long-tailed Weasel (*Mustela frenata longicauda*) near Fort Saskatchewan, Alberta. See article by Garry Hornbeck on pages 131-137 in this issue. Photo by Gordon Court.



The Response of Invertebrate Populations in Three Undisturbed Soils in Southwestern Ontario, Canada, to Variations in Local Soil Properties, Seasonal Changes, and Climate

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1310 Hillcrest Drive, Sarnia, Ontario N7S 2N4 Canada; (519) 542-9726

Harris, I. W. E. 2013. The response of invertebrate populations in three undisturbed soils in southwestern Ontario, Canada, to variations in local soil properties, seasonal changes, and climate. *Canadian Field-Naturalist* 127(2): 103–117.

Three distinctly different undisturbed mature forested sites at the northern limits of the Carolinian forest system in Lambton County, Ontario, were examined to test the hypothesis that the abundance of each order of soil invertebrates captured is dependent on a unique set of soil properties, seasonal changes, and climate variations. Sixteen independent variables were recorded over five consecutive years. With the exception of rainfall, air temperature, and soil temperature, means of the measured variables differed significantly ($P < 0.05$) among soils. Twenty-eight taxa of invertebrates were captured, of which Acari, Collembola, and Nematoda were most abundant. Only the mean of total abundance and the mean abundance of Acari, Nematoda, and Haplotoxida differed significantly ($P < 0.05$) among soils. Haplotoxida was the only taxon in all three soils found to be influenced significantly ($P < 0.05$) by seasonal variation. The usual mid-summer minimum in the abundance of Haplotoxida was latest and most clearly defined in the clay soil and earliest and least clearly defined in the sand soil. Regression analysis showed that each site is sufficiently separated in the factor space observed that the abundance of each invertebrate taxon is dependent on different combinations of local variables. The hypothesis was rejected.

Key Words: micro-invertebrates; abundance; richness; soil properties; self-organization; climate; seasonal effect; Haplotoxida; Carolinian forest; Ontario; Canada

Quantitative data on the character of invertebrate populations in undisturbed mature soils and their dependence on the environmental and seasonal variables can provide a baseline against which changes resulting from forestry or agricultural activity or from proximity to industrial or urban centres can be evaluated. The scarcity of such data has long been recognized, as reported by Marshall et al. (1982) in an extensive review of the need for more research on Canadian soil arthropod populations. In a subsequent review, Marshall (2000) again noted the need for baseline studies to allow the impact of forest harvesting practices to be evaluated.

Recently, several studies have been undertaken to gather data on undisturbed soils. Addison et al. (2003) reported a multi-year study of invertebrates captured from ground litter on undisturbed forest floor on Vancouver Island, British Columbia. Soil and climate data were not reported. Also in British Columbia, Berch et al. (2006) reported data on the response of some soil invertebrates to enhanced levels of nitrogen in evergreen forest plots that had been clear-cut 30 years previously. A detailed study of the correlations of fungi with soil biota in the United Kingdom includes limited data on effects of seasonal variation and soil properties on selected invertebrates (Krivtsov et al. 2004). The relationships between some soil invertebrate populations and soil properties have been investigated by Hishi et al. (2006) in “natural” forests in Japan. Sylvain and Buddle (2010) studied oribatid mites in the soils of undisturbed hardwood forests in southern Quebec.

The Centre for Ecology and Hydrology in the United Kingdom has been conducting periodic intensive surveys of the properties of undisturbed soils and the indigenous invertebrate populations throughout the United Kingdom since 1978. The most recent report from this group (Emmet et al. 2010) matched invertebrate abundance and richness with chemical and physical properties, producing a comprehensive picture of the current status of invertebrate populations in several different environments and long-term trends. Seasonal effects were not examined.

To contribute to the development of a more complete understanding of the dynamics of invertebrate populations in undisturbed soils, I conducted a five-year study (2005–2009) of several variables affecting the abundance and richness of invertebrate populations in three distinctly different undisturbed Carolinian forest sites in rural Lambton County, Ontario. The results of this study apply only to the three sites selected (other sites in Lambton County where these soil types are found would be expected to exhibit generally similar population structures but differ in detail). The hypothesis for this study was that the abundance of each invertebrate taxon captured at these sites was related to a unique combination of local environmental variables.

Methods

Study sites

The study area is in southwestern Ontario in the northeastern corner of Lambton County near the shore

TABLE 1. Independent variables recorded at each sampling in Lambton County, 2005 to 2009, and their definition.

Time	Climate	Soil	Surface biomass
Sampling week number counted from the first week of January (WEEKNO)	Total rainfall at Thedford, Ontario, for the 14-day period prior to each sampling (mm) (RMM)	Soil temperature at the time of sampling (°C) (SOILTMP)	Dry weight of ground litter (g/m ²) (DLIT)
		Percentage of water content of the soil at the time of sampling by weight (W)	
		Percentage of soil particles >0.05 mm by weight (WC)	
		Percentage of soil particles <0.05 mm and >0.002 mm by weight (WM)	
		Percentage of soil particles <0.002 mm by weight (WF)	
	Mean air temperature at Thedford, Ontario, for the 14-day period prior to each sampling (°C) (AIRTMP)	Soil bulk density (kg/L) (SOILBLKD)	Percentage of water content of ground litter by weight (LITW)
		pH (deionized water) (PH)	
		Available phosphorus (Olsen) (µg/g) (SPUGG)	
		Total phosphorus (Olsen) (µg/g) (PUGG)	
		Total nitrogen (Kjeldahl) (µg/g) (NUGG)	
		Total carbon (ignition) (µg/mg) (CUGMG)	

of Lake Huron (Figure 1). The underlying rock formation is reported by the Geological Survey of Canada (1969) to be part of the Middle Devonian Hamilton group, an argillaceous and crinoidal limestone. In this area, three types of soil, representative of 50% of the county, occur within a radius of 3 km: Brookston clay (Dark Grey Gleisolic, poorly drained), Brisbane loam (Grey Brown Podzolic, imperfectly drained), and Plainfield sand (Regosol, excessively drained) (Soil Survey of Lambton County 1979). The environment is rural, with the nearest urban/industrial centre (Sarnia) 50 km to the southwest. The study area is essentially free of urban/industrial stresses, except for long-range atmospheric deposition. The land varies from 5 to 20 m above mean lake level, including a line of dunes along the lake. A few small creeks drain to the north.

Level sites, 50 m², were selected for sampling in forests growing in the above soil types. On the UTM grid, the centres of these sites are as follows:

Plainfield sand	4785380 northing	427425 easting
Brookston clay	4783420 northing	426610 easting
Brisbane loam	4781325 northing	424375 easting

The loam site is near plot number of the Ontario Hardwood Forest Survey (4780990 northing, 424965 easting), as reported by McLaughlin et al. (2000).

Tree ring counts showed the soil in each of the sites chosen had not been disturbed for at least 200 years. The loam site differed from the clay and sand sites in that it had a more dense understory of shrubs and vines. All three sites exhibited moder type humus formation, as described by Green et al. (1993).

Total rainfall and mean air temperature data for the 14-day period preceding each sampling were obtained from the Environment Canada weather station about 6 km to the southeast at Thedford (Environment Canada 2005–2009*).

Field methodology and processing of soil biota

Lists of the abbreviations used in the following text, figures and tables and their definitions are provided in Table 1 and Table 4. A set of soil samples was collected at each site of 50 m² once in the spring (weeks 21–23 counting from the first week of January), once in the summer (weeks 32–34), and once in the autumn

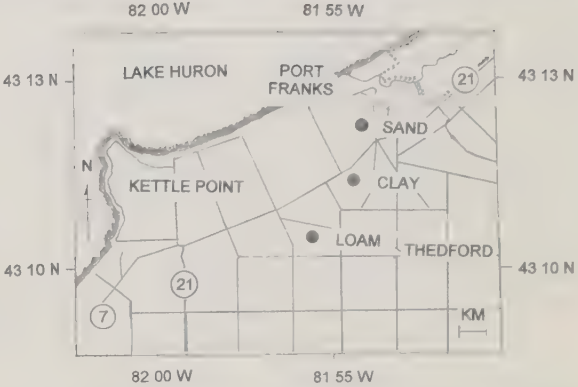


FIGURE 1. Sampling sites in Lambton County, Ontario, 2005 to 2009.

(weeks 42–44) of 2005–2009 inclusive (15 samples per soil type, 45 samples in total). In 2005 and 2008, each site was surveyed to establish the genera of trees present.

Before invertebrate sampling was done, ground litter and growing vegetation were removed down to the mineral soil from a randomly selected sampling plot of 1 m² and placed in a sealed tared plastic bag. The air-dried weight of the collected material is considered to be a measure of the above-ground biomass present. Each plot sampled was flagged to prevent resampling at the same point.

The ground litter samples were weighed as taken and then dried to a constant weight at room temperature to estimate the above-ground biomass present and the water content.

A large sample, 26 cm in diameter and 5 cm deep, was taken within each cleared sampling plot of 1 m² and placed in a sealed, tared plastic bag. This sample was weighed as taken to estimate the soil bulk density. Subsamples were removed from this sample to estimate water content, particle size distribution, and chemical composition. In 2007, at each sampling, two supplementary small core samples were taken to evaluate the sampling and analytical error of the chemical analyses. Soil temperature was measured at each sampling.

Water content was measured by drying two subsamples of 50–60 g each to a constant weight at 120°C.

Soil particle size distribution was estimated using the hydrometre method described by Day (1965). Chemical analyses for total nitrogen (Kjeldahl), total carbon (ignition), total and available phosphorus (Olsen), and pH (deionized water) were performed by Agriculture and Agri-Food Canada (Harrow, Ont.). The analytical procedures used were those of Carter and Gregorich (2008).

From each cleared plot of 1 m², eight soil core samples, 5 cm in diameter and 5 cm deep, were taken at each season over the five-year period. These were held in a cooled container for the invertebrate extraction process, which was started within four to six hours after the samples were collected. Annelid worms were extracted from a closely adjacent plot 50 cm² using the hot mustard technique (Clapperton et al. 2008).

Four of the small core samples were extracted separately to estimate the abundance of Nematoda present in each plot using the Baerman funnel technique described by Shurtleff and Averre (2000). The remaining four small cores were used separately to extract other micro-invertebrates using the Merchant-Crossley high-gradient extractor, as modified by Norton (1986). For both sets of four core samples, extractions were run for seven days under temperature control (25–35°C) using 7-watt incandescent bulbs as the heat source in insulated cells. The Baerman extractions were run using chlorine-free aerated water. In the case of the high-gradient extractions, the invertebrates were captured in a water solution (0.05% vol.) of liquid detergent.

All the organisms larger than 0.1 mm were identified to the order level (Collembola, and Haplotaenidia were identified to the family level) and counted under water using a stereo microscope at 10× and 40× magnification. Several keys were used (Borror and White 1970; Barnes 1974; Reynolds 1977; Bland and Jaques 1978; Arnett et al. 1980; Chu and Cutkomp 1992).

Invertebrates of each taxon were preserved separately in a 70% isopropanol/water solution containing 0.2% glycerin and stored in screw-topped glass containers. This archive has been deposited in the laboratories of Agriculture and Agri-Food Canada at Harrow, Ontario.

Data processing

A field study of soil invertebrates is usually constrained by the existing values of the many independent variables in the factor space under examination, namely the physical, chemical, and climate characteristics of the locality. The investigator cannot set the values of the independent variables at the levels most useful for identifying the dominant effects on the dependent variables. Under such conditions, analysis of variance (ANOVA) and regression analysis are the most helpful techniques for determining differences and trends, which may then be examined under more controlled conditions. However, for all types of analy-

sis, care must be taken to separate cause and effect from mere correlation.

Statistical analysis was performed using software developed by the Centres for Disease Control and Prevention in Atlanta, Georgia (EPI6, version 6.04d), and Systat 11. Statistical significance was set at the 95% confidence level for analysis of variance. For the regressions, significance was claimed if the 95% confidence limits of the coefficients for the independent variables did not include zero.

For multiple regressions, relative significance of each independent variable was established using the forward selection procedures described by Christensen (2001) and Draper and Smith (1981). Backward selection was then used to develop any significant first order multiple regressions using those independent variables with *F* values greater than 1.0. Second-order models were tested if the data showed strong curvature.

Draper and Smith (1981) suggest, with reference to work by G. E. P. Box and J. M. Wetz, that the regression *F* should exceed the value in the *F* distribution table for 95% confidence at the appropriate degrees of freedom by a factor of at least four if the correlation is to be considered a satisfactory predictor. The regression *F* values that meet this criterion are identified in the tables. The partial *F* test noted in the tables is a measure of the relative power of multiple significant variables in accounting for the variation in the dependent variable.

A copy of the complete database for this study is available from the author in several commonly used software systems.

Results

Soil properties

The distribution of tree genera in the three sample sites is shown in Figure 2. *Prunus*, *Tilia*, *Populus*, *Acer*,

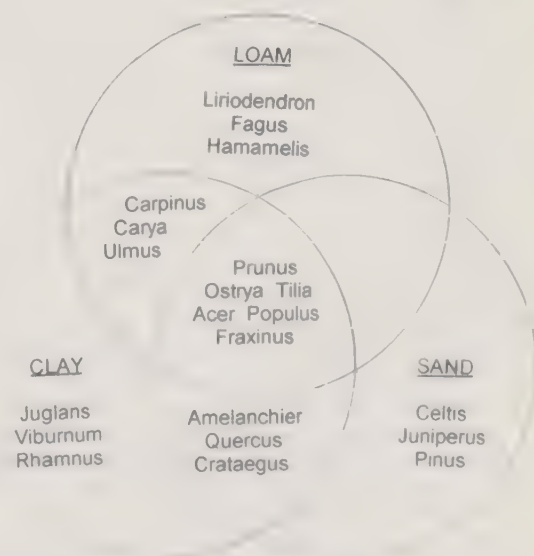


FIGURE 2. Genera of trees on the sampling sites in Lambton County, 2005 to 2009.

Ostrya, and *Fraxinus* were common to all three. *Pinus*, *Juniperus*, and *Celtis* were found only in the sand site. *Liriodendron*, *Fagus*, and *Hamamelis* were found only in the loam site, while *Juglans*, *Rhamnus*, and *Viburnum* occurred only in the clay site. The clay site harboured the greatest number of genera.

The spring-to-autumn variation in climate causes a closely similar weekly variation in soil temperature in all three sites. Figure 3 shows the variation for all three sites combined. The mean soil temperature for the spring samplings was 15°C, for summer was 19°C, and for autumn was 10°C.

The means and the associated standard error of the physical and chemical properties of the soils at each site are recorded in Table 2. For those properties showing significant differences between means ($P < 0.05$), the observed scatter is illustrated in Figures 4a to 4e. Analysis of variance showed that, all soil properties except for total rainfall fourteen days prior to sampling, mean air temperature fourteen days prior to sampling and soil temperature at the time of sampling showed that significant differences ($P < 0.05$) existed between sample plots within each site.

Many of the variables measured to establish the character of the soils at the sampling sites were significantly correlated ($P < 0.05$). By definition, some

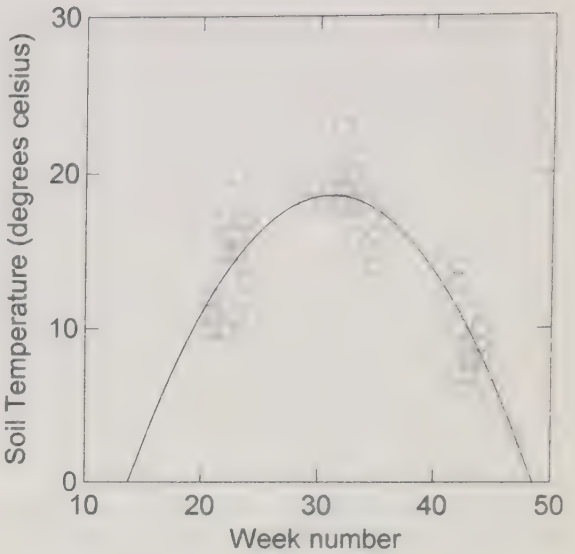


FIGURE 3. Soil temperature at the time of sampling in Lambton County, 2005 to 2009.

have correlation coefficients of 1.0, for example the percentage of soil particles >0.05 mm, the percentage of soil particles <0.05 mm and >0.002 mm, and the percentage of soil particles <0.002 mm. Other variables

TABLE 2. Mean and standard error of climate and soil properties in Lambton County, 2005 to 2009, by soil type.

	Brookston clay			Brisbane loam			Plainfield sand		
	n	\bar{x}	se (+/-)	n	\bar{x}	se (+/-)	n	\bar{x}	se (+/-)
Total rainfall (mm)*	15	36.6	7.7	13	27.9	6.3	14	39.5	7.6
Mean air temperature (C)*	15	13.6	1.6	13	16.4	1.3	14	15.4	1.8
Soil Temperature (C)*	15	14.0	1.4	14	14.3	0.8	14	13.2	1.2
Percentage of water in soil by weight#	15	31.8	2.3	14	23.5	1.9	15	17.1	1.7
Percentage of soil particles >0.05 mm by weight#	15	55.0	1.5	14	78.0	1.2	15	89.2	1.4
Percentage of soil particles <0.05 mm and >0.02 mm by weight#	15	30.5	2.0	14	19.5	1.0	15	10.4	1.3
Percentage of soil particles <0.02 mm by weight#	15	14.4	2.3	14	3.1	0.7	15	0.3	0.1
Soil bulk density (kg/L)	15	1.255	0.05	14	1.192	0.04	15	0.910	0.05
pH	15	6.79	0.10	14	6.30	0.18	15	5.65	0.19
Available phosphorous (Olsen) (µg/g)	15	13.9	1.4	14	6.4	0.92	15	9.7	1.4
Total phosphorous (Olsen) (µg/g)	15	838	69.2	14	341	50.9	15	180	18.4
Total nitrogen (Keldjahl) (µg/g)	15	5178	350	14	3140	287	15	2378	295
Total carbon (ignition) (µg/mg)	15	80.6	4.82	14	54	3.79	15	57.8	7.49
Dry weight of ground litter (g/m^2)	15	692	58	14	1049	94	15	875	51
Percentage of water in ground litter by weight	15	43	3	14	30	4	15	38	4
Ratio of carbon to nitrogen (CNRATIO)	15	15.7	0.48	14	17.8	1.09	15	24.0	0.68
Ratio of carbon to total phosphorous (CPRATIO)	15	104	9.0	14	177	13.5	15	325	29.5
Ratio of carbon to available phosphorous (CSPRATIO)	15	6468	691	14	10050	1431	15	6301	534
Ratio of nitrogen to total phosphorous (NPRATIO)	15	6.64	0.56	14	10.0	0.66	15	13.4	1.08
Ratio of nitrogen to available phosphorous (NSPRATIO)	15	415	42.3	14	573	83.1	15	259	18.4
Ratio of total phosphorous to available phosphorous (PSPRATIO)	15	65.9	8.2	14	56.4	5.2	15	21.2	2.5

* ANOVA shows means do not differ significantly

Analysis run in duplicant or triplicate

Calculated variables: CNRATIO = (total carbon*1 000)/total nitrogen; CPRATIO = (total carbon*1 000)/total phosphorous; CSPRATIO = (total carbon*1 000)/available phosphorous; NPRATIO = total nitrogen/total phosphorous; NSPRATIO = total nitrogen/available phosphorous; PSPRATIO = total phosphorous/available phosphorous.

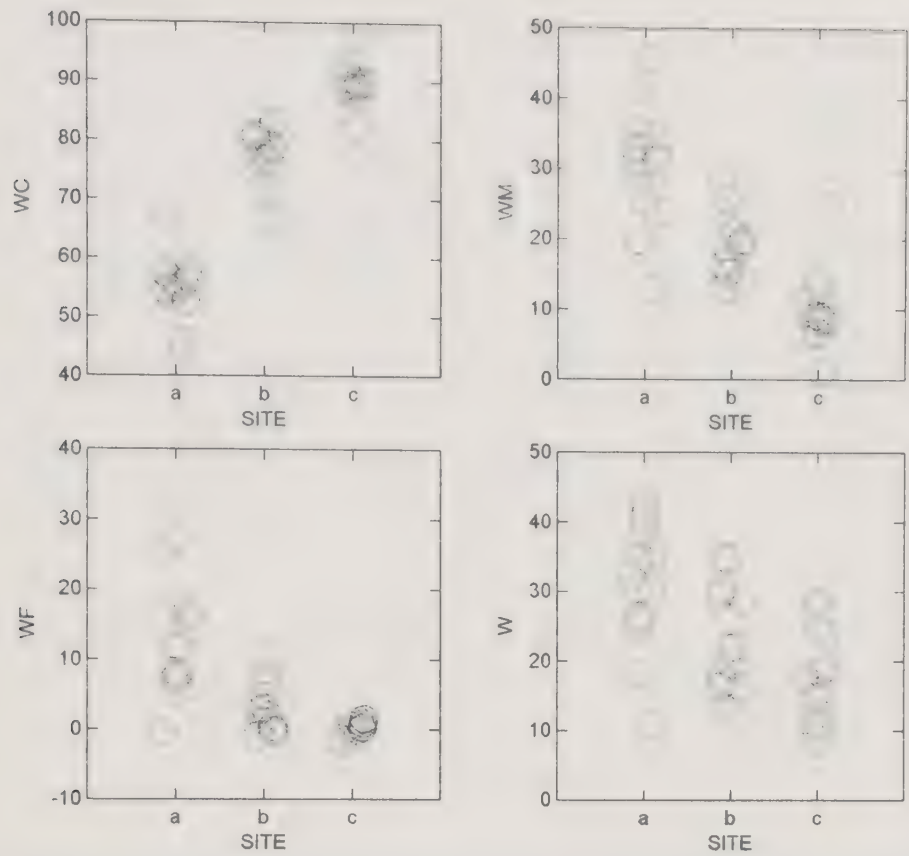


FIGURE 4a. Soil properties at each sampling site. WC = weight % of soil particles > 0.05 mm. WM = weight % of soil particles < 0.05 mm and > 0.002 mm. WF = weight % of soil particles < 0.002 mm. a = clay. b = loam. c = sand.

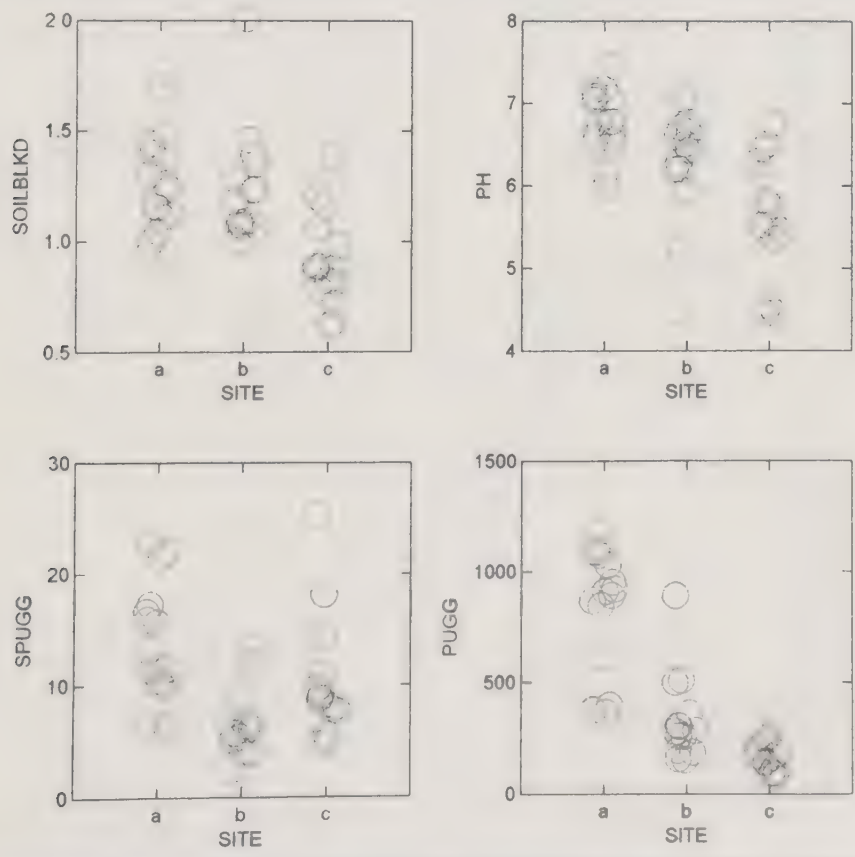


FIGURE 4b. Soil properties at each sampling site. SOILBLKD = soil bulk density (kg L⁻¹). PH = pH. SPUGG = available phosphorous (µg/g). PUGG = total phosphorous (µg/g). a = clay. b = loam. c = sand.

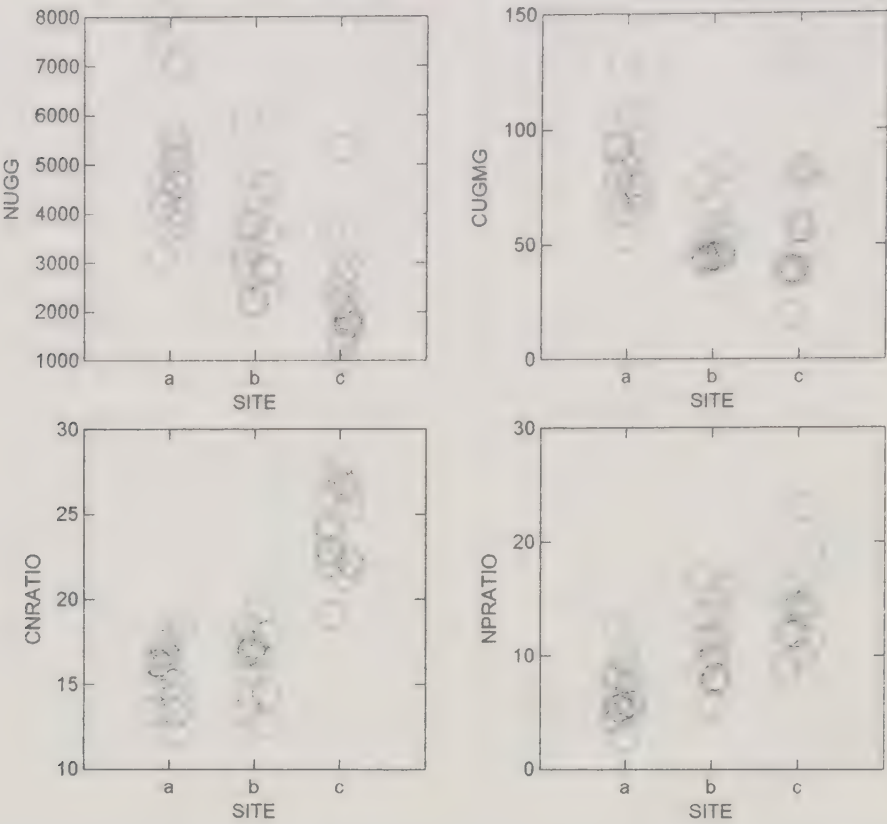


FIGURE 4c. Soil properties at each sampling site. NUGG = total nitrogen ($\mu\text{g/g}$). CUGMG = total carbon ($\mu\text{g/mg}$). CNRATIO = $(\text{CUGMG} \times 1\,000) / \text{NUGG}$. NPRATIO = $\text{NUGG} / \text{PUGG}$. a = clay. b = loam. c = sand.

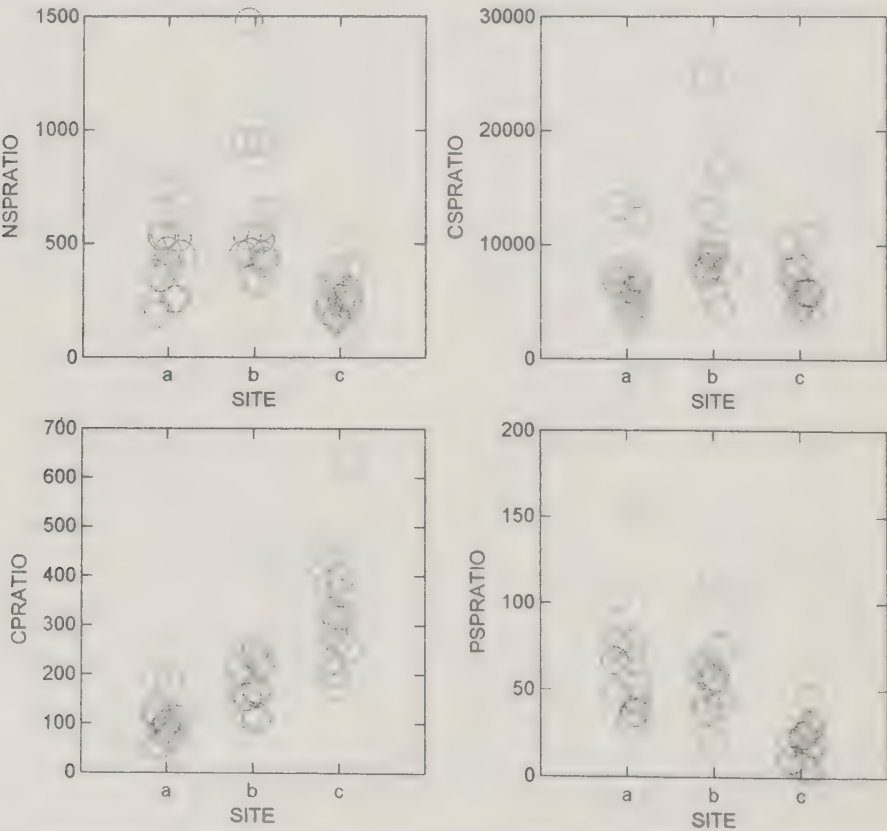


FIGURE 4d. Soil properties at each sampling site. NSPRATIO = $\text{NUGG} / \text{SPUGG}$. CSPRATIO = $(\text{CUGMG} \times 1\,000) / \text{SPUGG}$. CPRATIO = $(\text{CUGMG} \times 1\,000) / \text{PUGG}$. PSPRATIO = $\text{PUGG} / \text{SPUGG}$. a = clay. b = loam. c = sand.

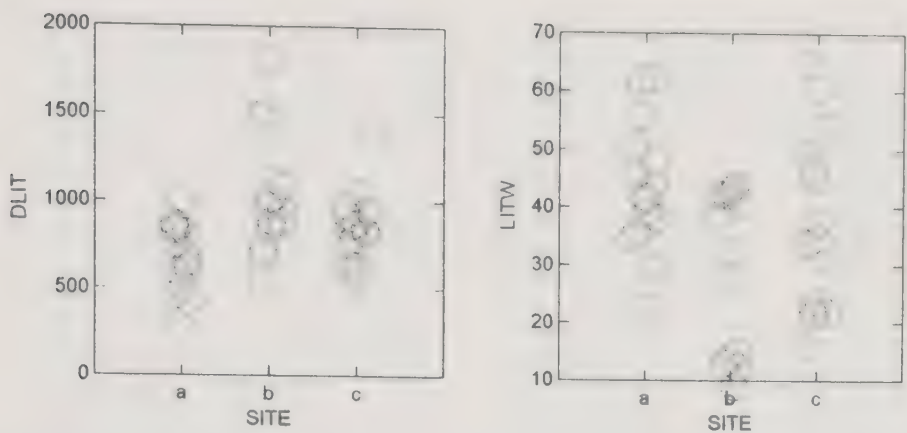


FIGURE 4e. Soil properties at each sampling site. DLIT = dry weight of ground litter (g/m^2). LITW = water content of ground litter (weight %). a = clay. b = loam. c = sand.

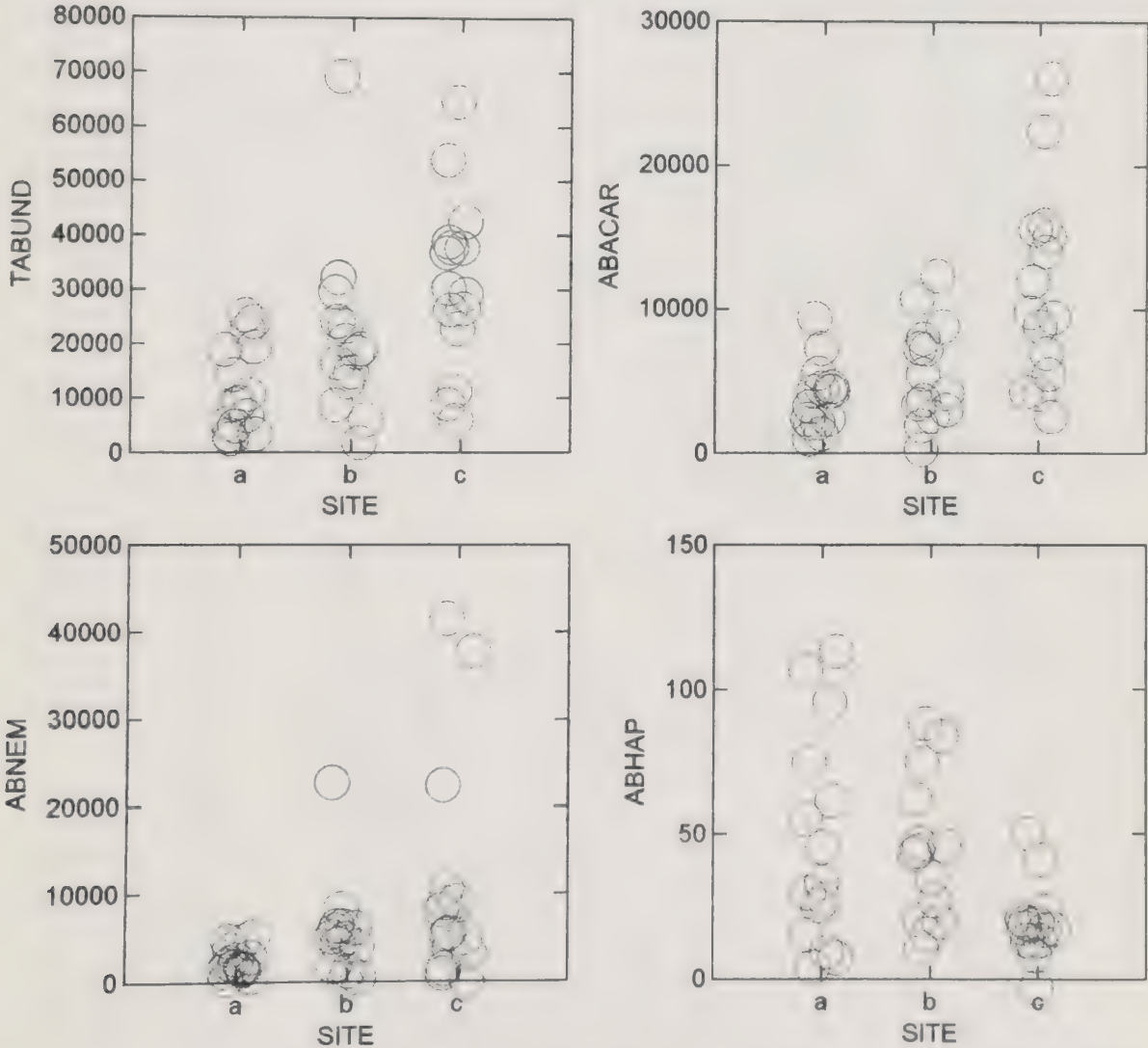


FIGURE 5. Invertebrate abundance at each sampling site. TABUND = total organisms m^2 , ABACAR = Acari m^2 , ABNEM = Nematoda m^2 , ABHAP = Haplotaxida m^2 . a = clay. b = loam. c = sand.

TABLE 3. Statistical details of significant ($P < 0.05$) regressions for soil properties in Lambton County, 2005 to 2009, all sites combined. Partial F in parentheses. Coefficients are rounded to two significant digits.

	Dependent variables						
	Soil temperature	Percentage of water content of the soil at the time of sampling by weight	Percentage of soil particles >0.05 mm by weight	Soil bulk density (kg/L)	pH	Total carbon (ignition) (µg/mg)	Dry weight of ground litter (g/m ²)
Week number	+3.8 (100)	—	—	—	—	—	—
Week number ^{1,2}	−0.06 (110)	—	—	—	—	—	—
Total rainfall	+0.10 (12)	—	—	—	—	—	—
Mean air temperature	—	−0.35 (6)	—	—	—	—	—
Percentage of soil particles >0.05 mm by weight	—	—	—	—	—	+0.56 (16)	—
Percentage of soil particles <0.002 mm by weight	—	+0.36 (6)	—	+0.020 (27)	—	—	—
Soil bulk density (kg/L)	—	+12 (8)	—	—	—	—	—
Available phosphorus (Olsen) (µg/g)	—	—	—	—	—	+1.4 (17)	−49 (19)
Total phosphorus (Olsen) (µg/g)	—	—	−0.03 (65)	—	—	—	—
Total nitrogen (Kjeldahl) (µg/g)	—	—	—	—	—	+0.013 (72)	—
Total carbon (ignition) (µg/mg)	—	+0.17 (16)	—	−0.0042 (10)	—	—	+8.4 (10)
Percentage of water content of ground litter by weight	—	—	—	—	—	—	−6.0 (6)
Ratio of carbon to nitrogen (CNRATIO)	—	—	+1.0 (13)	—	—	—	—
Ratio of carbon to total phosphorus (CPRATIO)	—	—	—	—	−0.0042	—	—
Ratio of total phosphorus to available phosphorus (PSPRATIO)	—	—	—	—	—	—	−3.1 (5)
Constant	−41	−1.2	+68	+1.3	+7.1	−38	+1200
r^2	0.78	0.76	0.82	0.40	0.44	0.86	0.45
F	72 ¹	22 ¹	91 ¹	14	33 ¹	82 ¹	8
n	43	43	43	43	43	43	43

¹Meets Box–Wetzel criterion for prediction

exhibited significant correlations, with low correlation coefficients caused by unmeasured variables or analytic error.

When the data for all three sites were combined, the significant correlations ($P < 0.05$) between soil properties (Table 3) were found. Some of these correlations can be readily rationalized. Observed relationships among the percentage of soil particles >0.05 mm, pH, and the dry weight of ground litter as dependent variables are probably mere correlations, while those for water content and soil bulk density are probably cause and effect. The correlation between total carbon as the dependent variable and total nitrogen, available phosphorus, and the percentage of soil particles <0.05 mm is noteworthy and is discussed further below.

The surveys reported by the Centre for Hydrology and Ecology in the United Kingdom (Emmett et al. 2010) cover a factor space much larger than that of this study in terms of the range of soil types examined. The soils in my study are most closely similar to the woodland and grassland soils in the United Kingdom. However, the available phosphorus levels in the soils in Lambton County are 20% to 50% lower.

Invertebrate populations

The invertebrates found are listed in Table 4 together with an indication of their presence in the three soils in approximate order of decreasing abundance. Of the 28 taxa found, 21 occurred in all three soils. Two orders of Acari and seven families of Collembola were

TABLE 4. Frequency of occurrence of organisms found in Lambton County, 2005 to 2009, in approximate order of decreasing abundance. “+” = present.

Taxon	Brookston clay	Brisbane loam	Plainfield sand
Abundance of taxa $>1000/m^2$			
Acari	+	+	+
Trombidiformes	+	+	+
Sarcoptiformes	+	+	+
Collembola	+	+	+
Onchyuridae	+	+	+
Isotomidae	+	+	+
Hypogastruridae	+	+	+
Poduridae	+	+	+
Entomobryidae	+	+	+
Sminthuridae	+	+	+
Neelidae	+	+	+
Nematoda	+	+	+
Abundance of taxa $<1000/m^2$ and $>300/m^2$			
Diptera	+	+	+
Coleoptera	+	+	+
Protrura	+	+	+
Abundance of taxa $<300/m^2$			
Paupopoda	+	+	+
Haplotaxida	+	+	+
Tardigrada	+	+	+
Diplura	+	+	+
Hymenoptera	+	+	+
Aranea	+	+	+
Plecoptera	+	+	+
Symphyla	+	+	+
Ephemeroptera	+	+	+
Hemiptera	+	+	+
Pseudoscorpiones	+	+	+
Juliforma	+	+	+
Blattodea	+	+	+
Isopoda	+	+	+
Geophilomorpha	+	+	+
Copepoda	+	+	+
Homoptera	+	+	+
Stylommatophora	+	+	+
Orthoptera	+	+	+
Thysanura	+	+	+
Lepidoptera	+	+	+
Neuroptera	+	+	+

identified. All Haplotaxida were found to be Lumbricidae.

Table 5 records mean abundance and the associated standard error for the most frequently captured invertebrates by soil type. Total abundance and richness (total number of taxa) are also included. Of those listed, only the mean abundance for the Acari, Nematoda, and Haplotaxida and mean total abundance exhibited significant differences ($P < 0.05$) among soils. For those means exhibiting significant differences ($P < 0.05$), the variation in abundance observed among sites and within sites is illustrated in Figure 5. The sand site showed the highest abundance for all but Haplotaxida.

Significant correlations ($P < 0.05$) were found between the mean abundance of several invertebrate taxa and soil properties, seasonal changes, and climate variables. Details of these correlations for those taxa found to have a significantly different ($P < 0.05$) mean abundance in the three soils are recorded in Table 6. Four can be considered robust relationships, having correlation coefficients (r^2) greater than 0.60. Two of the Haplotaxida correlations meet the Box–Wetz criterion for prediction. There is, however, little consistency in the pattern of independent variables with the exception of Haplotaxida. For those correlations, week number was the dominant independent variable.

Figure 6 illustrates the variation of Haplotaxida abundance with week number (WEEKNO) for the three

sites separately, as derived by second-order least squares modelling. The equations for these relationships are as follows:

Clay: Haplotaxida =
 $(-29.7 * WEEKNO) + (0.409 * WEEKNO^2) + 551$

Loam: Haplotaxida =
 $(-9.10 * WEEKNO) + (0.137 * WEEKNO^2) + 185$

Sand: Haplotaxida =
 $(-6.20 * WEEKNO) + (0.100 * WEEKNO^2) + 107$

The regressions for the clay and sand sites are significant ($P = 0.05$), but the regression for the loam site is not. The minima of abundance for the series clay/loam/sand occur at week numbers 36/33/31, respectively, and become more extended. The minima of abundance at those week numbers are 12/34/11, respectively.

Discussion

The data set developed in this study should be considered generally representative of similar soils in Lambton County. With the exception of the ongoing survey conducted by the Centre for Ecology and Hydrology in the United Kingdom, the available literature on undisturbed soils is focused on small regions in the total factor space affecting the dynamics of indigenous invertebrate populations. My study is intermediate in this regard.

TABLE 5. Abundance (mean number of organisms/m² ± standard error) and richness (total number of taxa ± standard error) of the most frequently captured invertebrate taxa in Lambton County, 2005 to 2009.

Taxon	Brookston Clay (n = 15)		Brisbane Loam (n = 14)		Plainfield Sand (n = 15)	
	\bar{x}	se (+/-)	\bar{x}	se (+/-)	\bar{x}	se (+/-)
Acari						
Trombidiformes	877	214	3 964	914	7 013	1 261
Sarcoptiformes	2 823	524	1 832	362	4 523	907
Subtotal*	3 699	656	5 795	1 056	11 537	1 727
Collembola						
Onchiyuridae	1 105	474	1 559	500	1 192	548
Isotomidae	1 911	734	1 061	575	1 113	373
Hypogasuridae	1 403	475	1 841	629	2 402	767
Poduridae	123	35	216	115	430	219
Entomobryidae	246	94	113	57	333	176
Neelidae	298	252	19	19	456	367
Sminthuridae	342	133	38	38	184	82
Subtotal	4 813	982	4 866	779	5 742	860
Nematoda*	2 043	411	5 532	1 566	10 713	3 306
Diptera	701	221	648	240	833	160
Coleoptera	88	38	188	71	324	159
Protrura	105	68	658	292	430	192
Pauropoda	35	20	160	84	254	147
Haplotaxida*	48	3	44	7	18	3
Total abundance*	12 496	2 001	21 094	4 454	32 157	4 459
Richness (total number of taxa captured)	8.4	0.6	9.5	0.4	9.5	0.7

* ANOVA shows these means differ significantly ($P < 0.05$)

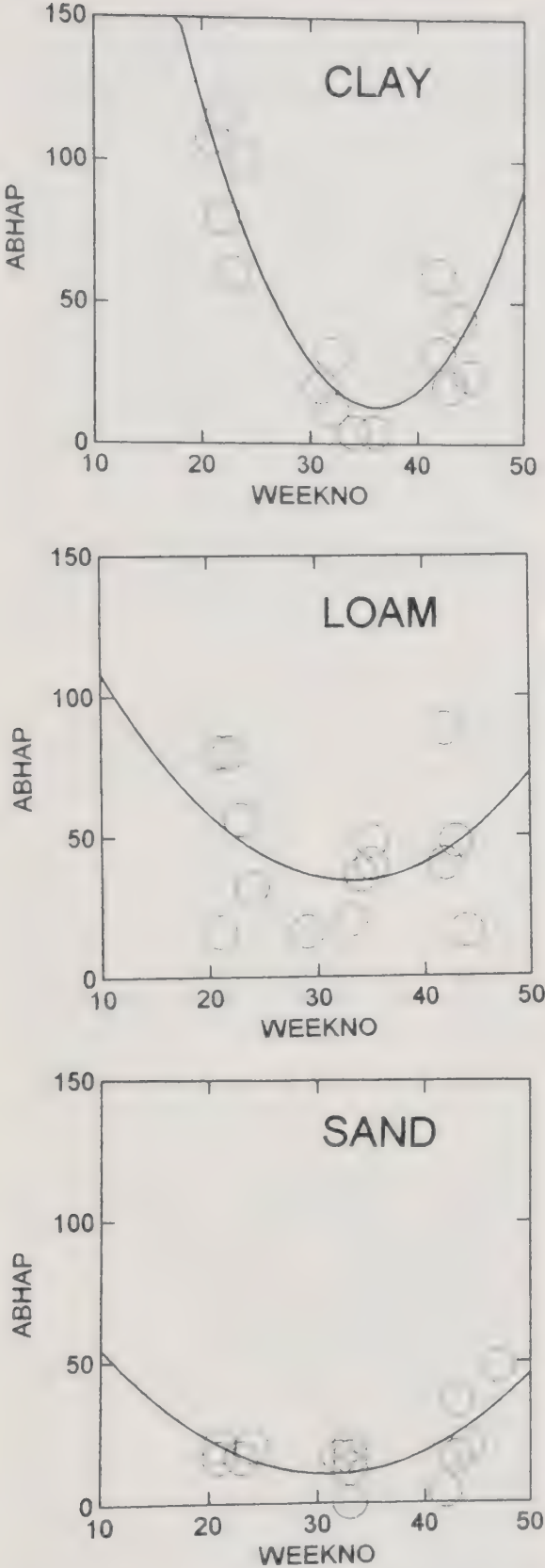


FIGURE 6. Seasonal variation in Haplotaxida abundance in the three soils in Lambton County, 2005 to 2009. ABHAP = Haplotaxida/m². WEEKNO = Sampling week number counting from the first week of January.

Soil properties

As noted above, the mean climate data reflect average conditions at the Environment Canada weather station at Thedford for spring, summer, and autumn and therefore do not differ significantly ($P < 0.05$). However, matching the weather data for the two-week period prior to each sampling with the sampling data provides a measure of the effect of local weather on soil and invertebrate populations. Furthermore, since the sampling sites are so close together, it is not surprising that the soil temperature profiles from spring to autumn are virtually identical. Nevertheless, the means of most soil properties at these sites (Table 2) differed significantly ($P < 0.05$).

Analysis of variance for those soil samples analyzed in duplicate or triplicate showed that statistically significant ($P < 0.05$) differences existed between sampling of plots 1 m² within each sampling site of 50 m², as illustrated in Figures 4a to 4d. Therefore, when conducting studies in undisturbed soils to determine the relationship between soil properties and invertebrate populations, it is necessary to measure soil properties in close proximity to the samples for invertebrate data.

The robust correlation found between the carbon content of the soil as the dependent variable and nitrogen, available phosphorus, and particle size distribution (Table 3) is of interest, since it suggests that mature undisturbed soils can develop a complicated, predictable balance of chemical properties over time. Higher levels of nitrogen (NUGG) and available phosphorus (SPUGG) in coarse soils were associated with higher total carbon content (CUGMG). Such a situation is difficult to rationalize. Exploring this relationship further revealed that, when the sites were examined separately, the relationships for the clay and loam sites were very similar, with only nitrogen (NUGG) as the significant ($P < 0.05$) variable. When the data for these sites were combined, the relationship was as follows:

$$\text{CUGMG} = (0.01 \cdot \text{NUGG}) + 16.4;$$

correlation coefficient: 0.92;
 $F = 142$ (meets the Box–Wetz criterion for prediction);
total degrees of freedom: 28.

For the sand soil, the relationship was:
$$\text{CUGMG} = (0.02 \cdot \text{NUGG}) - 1.4;$$

correlation coefficient: 0.96;
 $F = 314$ (meets the Box–Wetz criterion for prediction);
total degrees of freedom: 14.

Nitrogen is twice as potent in increasing the carbon content in the sand soil than it is in either the loam or the clay soil. This effect results in the development of a dense mat of the roots of small shrubs, weeds, and grass in the top 5 cm of sand. This mat is absent in clay and loam. The acidic nature of all three soils precludes the presence of carbonates, so the carbon content is present as decomposing ground litter or actively growing ground cover. The sand soil responds to higher levels of nitrogen by developing actively growing low ground cover more readily than either loam or clay

TABLE 6. Statistical details of significant ($P < 0.05$) correlations between invertebrate abundance and soil properties, climate, and seasonal variables, presented by taxon and total abundance. Coefficients are rounded to two significant digits. Only those taxa showing significant ($P < 0.05$) differences in means are shown.

Acari			
Clay:	$(-140 \cdot W) + (200 \cdot WC) - 2\,800$		
	$r^2 = 0.56$	$F = 8$	$n = 14$
Loam:	$(300 \cdot \text{WEEKNO}) - 3\,700$		
	$r^2 = 0.42$	$F = 9$	$n = 13$
Sand:	no significant correlation		
All sites combined:	$(-7\,300 \cdot \text{SOILBLKD}) + (-6.1 \cdot \text{PUGG}) - 18\,000$		
	$r^2 = 0.31$	$F = 9$	$n = 43$
Nematoda			
Clay:	no significant correlation		
Loam:	$(1\,100 \cdot \text{AIRTMP}) + (3\,600 \cdot \text{SPUGG}) + (-75 \cdot \text{PUGG}) - 9\,300$		
	$r^2 = 0.68$	$F = 6$	$n = 12$
Sand:	$(-11\,000 \cdot \text{PH}) + 71\,000$		
	$r^2 = 0.35$	$F = 7$	$n = 14$
All sites combined	$(-6\,100 \cdot \text{PH}) + 44\,000$		
	$r^2 = 0.27$	$F = 16$	$n = 43$
Haplotaxida			
Clay:	$(-31 \cdot \text{WEEKNO}) + (0.42 \cdot \text{WEEKNO}^2) + (0.34 \cdot \text{RMM}) + (24 \cdot \text{PH}) + (43 \cdot \text{SOILBLKD}) + (-0.25 \cdot \text{PSPRATIO}) + 360$		
	$r^2 = 0.97$	$F = 37\#$	$n = 14$
Loam:	no significant correlation		
Sand:	$(-8.0 \cdot \text{WEEKNO}) + (0.12 \cdot \text{WEEKNO}^2) + (0.26 \cdot \text{RMM}) + 130$		
	$r^2 = 0.81$	$F = 14\#$	$n = 13$
All sites combined:	$(-18 \cdot \text{WEEKNO}) + (0.26 \cdot \text{WEEKNO}^2) + (18 \cdot \text{PH}) + 210$		
	$r^2 = 0.43$	$F = 10$	$n = 43$
Total abundance			
Clay:	$(2\,900 \cdot \text{CNRATIO}) + (-430 \cdot W) - 20\,000$		
	$r^2 = 0.63$	$F = 10$	$n = 14$
Loam:	no significant correlation		
Sand:	no significant correlation		
All sites combined:	$(-3.3 \cdot \text{NUGG}) + (-7\,000 \cdot \text{PH}) + 77\,000$		
	$r^2 = 0.32$	$F = 10$	$n = 43$

Meets the Box-Wetz criterion for prediction

soil. Gunderson et al. (1998) reported a similar effect in sandy soils in northern Europe.

Invertebrate populations

Total abundance and the abundance of Acari and Nematoda increased across the series clay/loam/sand (Table 5 and Figure 5). For Haplotaxida, that trend was reversed. This result generally supports the findings of Hishi et al. (2008) and Sylvain et al. (2010)—that high density of fine root structure and conifer forests generally favour higher abundance of micro-Arthropoda. The data set for organisms showing significant ($P < 0.05$) differences between mean abundance of taxa and mean total abundance in the three soils was used to develop correlations (Table 6). Those for Acari show this taxon exhibited no consistent pattern of dependence on any particular set of variables, although a coarse, dry soil seemed to be favoured. This finding is supported by the control data reported by Berch et al. (2006), who showed a higher abundance of Acari in coarse, acidic soil with a lower nitrogen to available phosphorus ratio.

The correlations for Nematoda abundance showed a preference for more acidic soils, but again there was no clear pattern.

Abundance of Haplotaxida showed a consistent seasonal dependence and a positive relationship with pH and rainfall. The correlations for the clay and sand soils are both significant ($P < 0.05$) and robust. The significant ($P < 0.05$) positive effect of total rainfall for the 14-day period preceding sampling (as opposed to soil moisture at the time of sampling) supports the finding of Baker (1998), who reported that annual rainfall was a critical positive variable for Haplotaxida abundance in agricultural soils.

In the three soils studied here, the consistent trend to earlier and more extended minima in the abundance of Haplotaxida across the series of clay/loam/sand (Figure 6) suggests a relationship between the timing of the diapause behaviour of various Lumbricidae or some other seasonal variation not investigated in this study. Millican et al. (2007) reported that different soil compositions exhibit minima in Haplotaxida abundance at

different times in predominantly clay soils with different histories of disturbance. Both Millican et al. and Pothoff et al. (2008) reported a positive effect of pH.

If the seasonal soil temperature profiles of the three soils had been different, it is probable that soil temperature would appear as a significant ($P < 0.05$) variable (Edwards et al. 1972). It is noteworthy that the carbon to nitrogen ratio for all three soils is higher than the optimal range for Haplotaxida reported by Lee (1985).

Data reported Berch et al. (2006) and Emmet et al. (2010) for invertebrate abundance in conifer-forested sandy soil in British Columbia and Great Britain respectively exemplify the range of abundance commonly found. The abundance of Acari and Collembola combined in the British Columbia soil is about 95 000 m⁻². In the Great Britain soil the comparable abundance is about 3 000 m⁻². For Lambton County, this abundance is intermediate at about 18 000 m⁻². Even allowing for the inevitable differences in sampling and processing, such a variation indicates that the organisms have been exposed to entirely different locations in the multivariate factor spaces of soil and climate.

The lower correlation coefficients for the relationships derived for the combined data (Table 6) result in part from variation introduced when the effects of different soil environments are introduced into the calculations.

The complexity of the relationships between soil properties and the dynamics of invertebrate population is illustrated by the response surfaces for richness and abundance in Figure 7 and Figure 8. In these figures, data for all three soils have been combined to produce a least squares approximation at maximum tension. The independent variables in Figure 7 are physical properties of the soil (percentage of coarse particles and soil temperature) selected from the list of properties as being orthogonal and therefore distributed most evenly in the factor space. In Figure 8, the independent variables are chemical properties of the soil (pH and available phosphorus) selected using the same criterion. The irregular character of these surfaces shows why calculation of simple first- or second-order approximations, even with several independent variables, achieves statistical significance ($P < 0.05$) with difficulty.

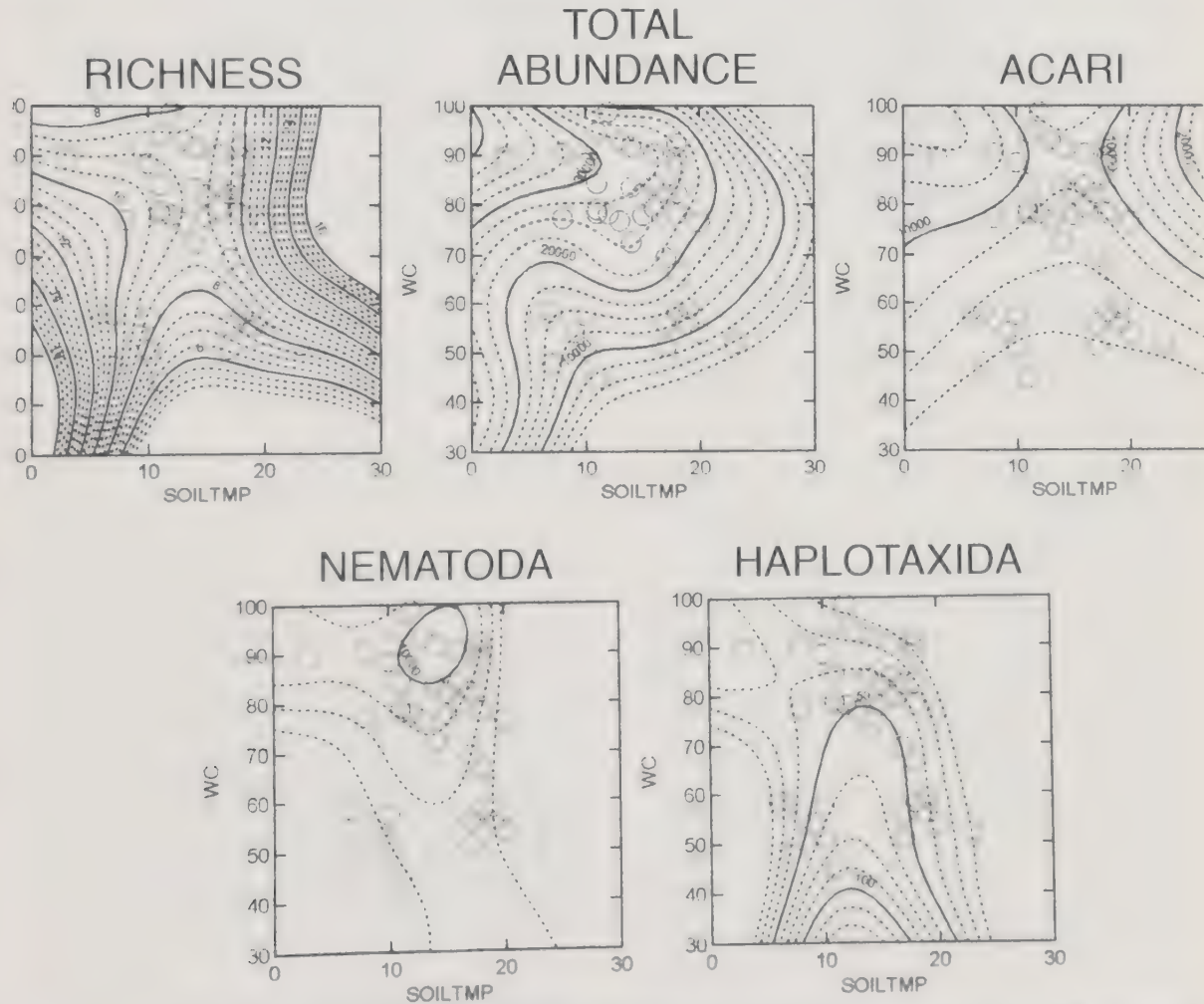


FIGURE 7. Response surfaces for richness and abundance in relation to two physical properties of the soils: WC = percentage of soil particles >0.05 mm by weight. SOILTMP = soil temperature at the time of sampling (Celsius).

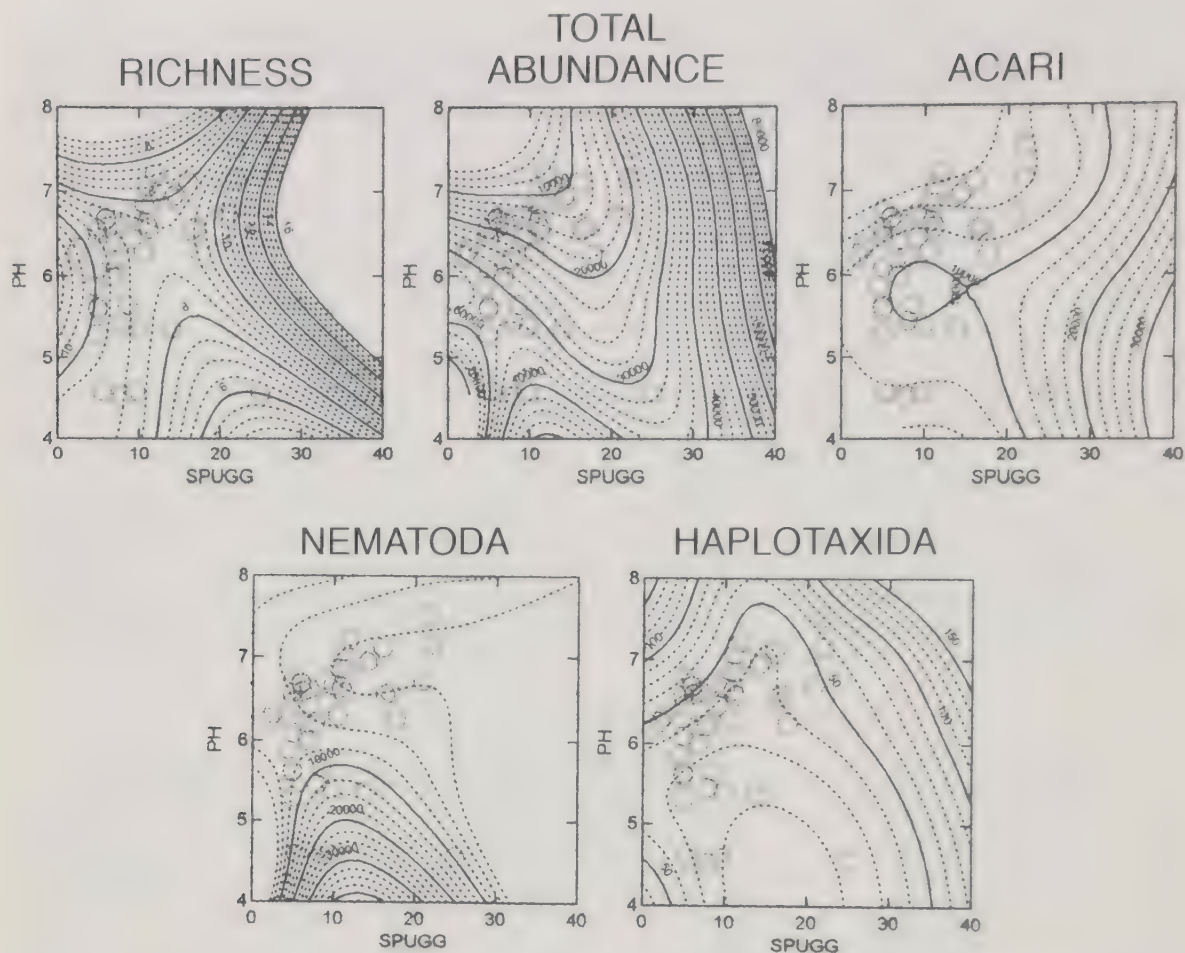


FIGURE 8. Response surfaces for richness and abundance in relation to two chemical properties of the soils. PH = pH. SPUGG = available phosphorous (Olsen) ($\mu\text{g/g}$).

It is apparent that the three soils examined here are sufficiently separated in the multivariate factor space that differences in the balance of independent variables are critical in changing the response of richness and abundance of individual invertebrate taxa. Krivtsov et al. (2004) observed a similar effect in forested soils in the United Kingdom. The absence of an independent variable in the correlations recorded in Table 6 does not mean that it is unimportant. For a soil occupying another location in the factor space, it might have a significant effect. Furthermore, the high level of adaptability of soil invertebrates is evident from the fact that, in all three distinctly different soils, most of the taxa found were present in all three (Table 4).

Finally, the finding of statistically significant ($P < 0.05$) correlations (Table 6) is evidence, in the three soils studied here, of the self-organization tendency found in wild populations (May 1991). Such systems can oscillate in abundance over time between a chaotic state and an ordered state. Many populations found in this study were in an ordered state for a period of five years over an area of 50 m^2 in at least one soil.

The hypothesis that abundance of each taxon of invertebrates captured is dependent on a unique set of

soil properties, seasonal variables, and climate was not supported by this study.

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Temporal Variation in Food Habits of the American Black Bear (*Ursus americanus*) in the Boreal Forest of Northern Ontario

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We used scat analysis to investigate temporal variation in the food habits of American Black Bears (*Ursus americanus*) in the boreal forest of northern Ontario. Specifically, we examined whether there was a seasonal shift in foraging over three years (1990–1992) and which foods, if any, varied in occurrence among years. American Black Bears ate foods ranging from green vegetation in the spring to ants in mid-summer and berries and nuts in late summer and fall. Late summer berry forage, especially blueberries (*Vaccinium* spp.), varied greatly among years. American Black Bears in northern Ontario consumed a variety of foods opportunistically. Understanding how American Black Bears in northern Ontario exploit food resources and how these food items vary among years can provide insights into demographic processes and help wildlife managers better anticipate changes in the structure of the harvest of American Black Bears and in human–bear conflict levels. In northern Ontario, forest management practices that increase the availability of early successional species would be beneficial to American Black Bear populations.

Key Words: American Black Bear; *Ursus americanus*; *Vaccinium angustifolium*; Early Lowbush Blueberry; *Vaccinium myrtilloides*; Velvet-leaved Blueberry; annual variability; boreal forest; diet; feeding ecology; food habits; foraging; scat analysis; Ontario

Studies of food habits of American Black Bears (*Ursus americanus*) have covered an array of climatic and geographical locations, from Alaska to Virginia (Hatler 1972; Landers et al. 1979; Beeman and Pelton 1980; Hellgren and Vaughan 1988; Raine and Kansas 1990; Holcroft and Herrero 1991; Schwartz and Franzmann 1991; Boileau et al. 1994; Kasbohm et al. 1995). Nevertheless, such studies should be replicated geographically and temporally because the type, phenology, and relative abundance of foods consumed by American Black Bears vary from location to location and season to season. Natural foods can also vary in abundance among years, significantly affecting survival and reproductive success of American Black Bears (Rogers 1976, 1987; Czetwertynski et al. 2007; Obbard and Howe 2008) as well as space use patterns (Powell et al. 1997).

Variation in the phenology and abundance of natural foods among years has been linked directly to variation in numbers of American black bears that are harvested (Ryan et al. 2004), to changes in the structure of the harvest of American Black Bears (Noyce and Garshelis 1997), and to variation in levels of conflict between humans and American Black Bears (Howe et al. 2010). Adult female American Black Bears are more vulnerable to hunting pressure in the fall during years of food failure (Noyce and Garshelis 1997). As a result, in Ontario, wildlife managers monitor both the total num-

ber of American Black Bears harvested and the proportion of females in that harvest to ensure they remain within sustainable levels (McLaren et al. 2009*). Due to the importance of adult females in the population dynamics of American Black Bears (Obbard and Howe 2008), outfitters and other hunters are encouraged to direct harvest towards males (Obbard et al. 2008).

Here we report on the food habits of American Black Bears in the boreal forest of northern Ontario, an understanding of which could help explain variations in the American Black Bear harvest and in levels of conflict between humans and American Black Bears. This knowledge could help wildlife managers understand when to expect increases in the proportion of adult females in the harvest and when to anticipate changes in levels of conflict between humans and American Black Bears.

Because annual variation in natural foods of bears is common, studies of more than two years' duration are necessary to capture annual fluctuations and trends (Korschgen 1980; McLellan and Hovey 1995). Our objectives were (1) to document general food habits of American Black Bears in the boreal forest of Ontario and (2) to determine, over a three-year period, whether there was seasonal and yearly variation in the proportions of food items ingested by American Black Bears in the boreal forest.

Study Area

The study area was located approximately 25 km north of Chapleau, Ontario, in the southeastern portion of the Chapleau Crown Game Preserve (48°10'N, 83°20'W; Figure 1). A variety of logging roads crisscrossed the 400-km² study area, which was within the Missinaibi–Cabonga Forest Section of the Southern Boreal Forest Region (Rowe 1972). During 1990–1992, mean temperatures in January and July were –13.6°C and 15.7°C, respectively; mean annual precipitation was 87.5 cm (Chapleau Station, 47°49'12"N, 83°20'48"W; Environment Canada 2013). The study area was dominated by typical boreal forests with monoculture stands of Jack Pine (*Pinus banksiana*) and spruces (*Picea* spp.) along with mixtures of mature boreal mixedwood stands with intermediate successional and recently logged (10–20 years previously) and replanted areas.

Logging and periodic wildfires resulted in a mosaic of different-aged forest stands (Ontario Ministry of Natural Resources 1984*). Major overstory species were Jack Pine, Black Spruce (*Picea mariana*), White Spruce (*Picea glauca*), Balsam Fir (*Abies balsamea*), Trembling Aspen (*Populus tremuloides*), Paper Birch (*Betula papyrifera*), Eastern White Cedar (*Thuja occidentalis*), and Tamarack (*Larix laricina*), with abundant alders (*Alnus* spp.), Mountain Maple (*Acer spicatum*), Balsam Poplar (*Populus balsamifera*), and willows (*Salix* spp.) in the understory. Important fruit-producing species in the understory and ground cover were Pin Cherry (*Prunus pensylvanica*), serviceberries (*Amelanchier* spp.), mountain-ashes (*Sorbus* spp.), Beaked Hazelnut (*Corylus cornuta*), Early Lowbush Blueberry (*Vaccinium angustifolium*), Velvet-leaved Blueberry (*V. myrtilloides*), Bunchberry (*Cornus canadensis*), raspberries (*Rubus* spp.), currants (*Ribes* spp.), Bristly Sarsaparilla (*Aralia hispida*), and Wild Sarsaparilla (*A. nudicaulis*).

Methods

Scat analysis is a common technique used to study food habits of carnivores (Klare et al. 2011); however, it can be tedious and labour-intensive, due to the effort required to identify fecal remains. As a result, a number of techniques have been developed to reduce the time required for effective scat analysis. These techniques vary from visual estimates (Tisch 1961; Hatler 1972) to visual volume estimates (Grenfell and Brody 1983; Irwin and Hammond 1985) coupled with frequency of occurrence. Other researchers have used point sampling (Boileau et al. 1994) and volume measured by water displacement (Landers et al. 1979; Holcroft and Herrero 1991).

Because information on dry mass of food items is essential to studies of nutrition or food energetics (Korschgen 1980; Robbins et al. 2004), we elected to base our scat content estimates on the mass of dried, hand-sorted food items in order to make our data avail-

able for any future nutritional studies. We also report frequency of occurrence to enable comparison with other studies.

Holcroft and Herrero (1991) arbitrarily suggested that a 25% subsample should be representative of an entire scat. However, we developed a subsampling technique that showed that a 10% subsample of each scat was representative of the contents of the entire scat. To determine this, we thoroughly mixed and homogenized one randomly selected dried scat from each season on a dissecting tray and divided each into subsamples. We then compared the contents of 10%, 25%, and 65% subsamples by mass using Spearman rank correlation and found no difference among the three subsample sizes ($P > 0.05$), suggesting that a 10% dry mass subsample of each scat was sufficient for analysis (Romain 1996).

During May–October 1990–1992, we collected scats daily along a 30-km network of tertiary gravel roads throughout the study area, and occasionally from live traps used to capture American Black Bears for a demographic study (Obbard and Howe 2008). In order to limit bias from anthropogenic sources, we did not collect scats from within a 2-km radius of a small landfill in the study area; this approximated the average radius of the home range of adult female American Black Bears in the area (Schenk et al. 1998). Scats therefore typically contained only naturally occurring foods.

We placed scats separately in labeled plastic bags and froze them at –20°C within 4 hours of collection. For analysis, we thawed individual scats, strained them by washing through three-layered mesh sieves (Precision Scientific Co., Chicago, Illinois; aperture sizes 5.0, 2.0, and 0.833 mm) to remove small fragments, and then dried them to a constant mass in a drying oven at 40–50°C for 24–48 hours. We assigned scats to five periods: May, June, July, August, and September–October (September and October were combined because of the small sample sizes).

In order to monitor seasonal availability of plant species that we might expect to find in scats and to obtain representative specimens for comparison with scat contents, we compiled phenological data within major habitat types on a weekly basis from early May to August 1990–1992. We sampled 20 10-m² quadrats selected to represent all major habitat types in the study area. We monitored development of a few plant species not found in the quadrats in areas near established quadrats or along roadsides.

After consulting a reference list of plants for the study area (Brunton 1982*), we collected reference samples of potential food items at different phenological stages during 1991, 1993, and 1994, including leaves, berries, and seeds. We collected hairs of known specimens of potential prey animals from carcasses encountered. We also identified food items from fresh scats; this helped us to identify the components of

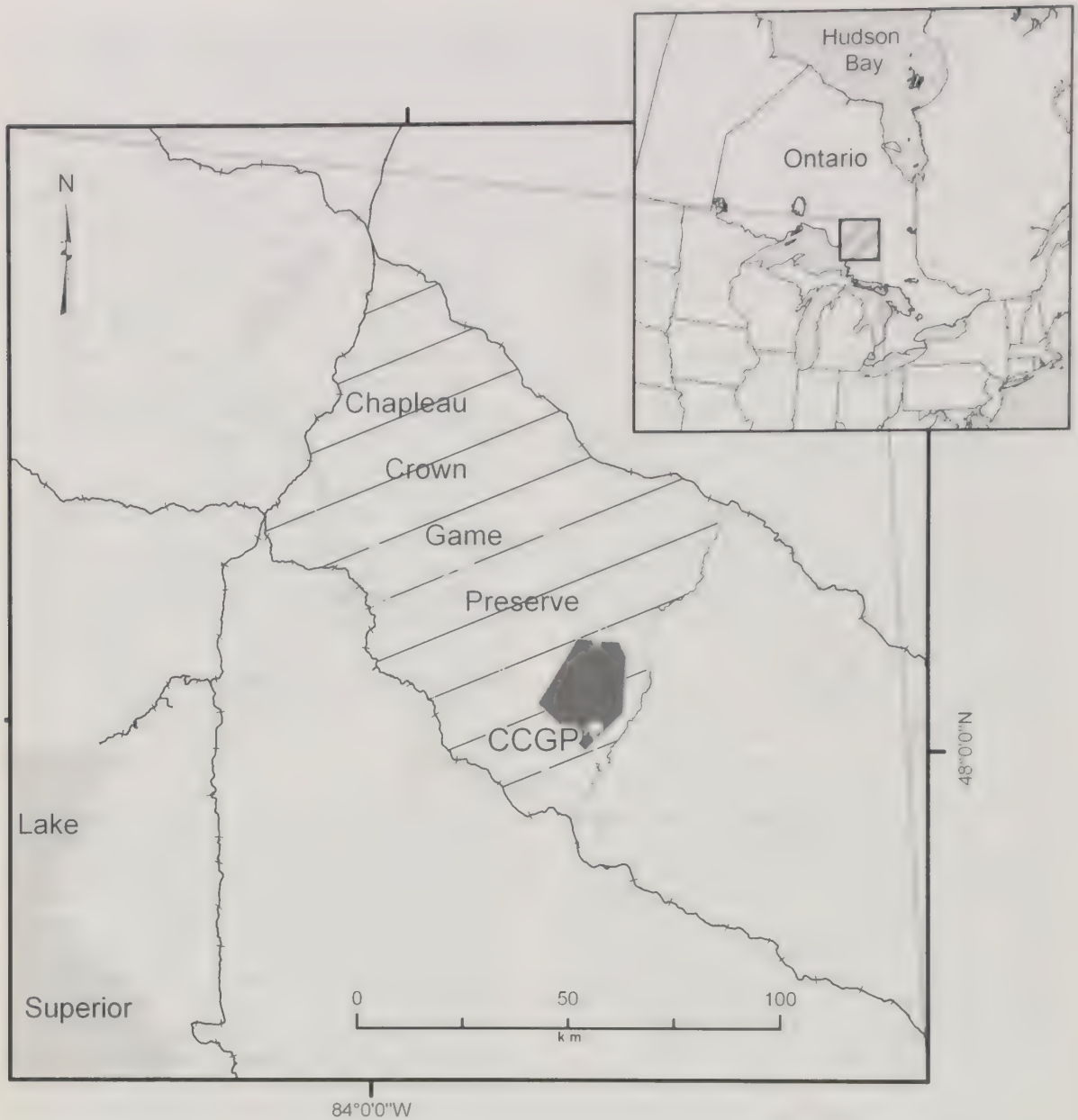


FIGURE 1. Location of study area (black polygon) in the southeastern portion of the Chapleau Crown Game Preserve in northern Ontario, 1990-1992. Inset shows location of Chapleau Crown Game Preserve and surrounding area relative to the rest of the province.

dried scats. We used keys and manuals to identify grasses (Musil 1963; Brown 1979), herbaceous plants, shrubs, and trees (Petrides 1958; Symonds 1963; Peterson and McKenny 1968; Soper and Heimbürger 1982; Baldwin and Sims 1989), fruits and seeds (Martin and Barclay 1961; Musil 1963; Montgomery 1977), insects (Bland 1958), and mammal hairs (Adorjan and Kolenosky 1969*; Moore et al. 1974; Thompson et al. 1987). We attempted to separate all species of forbs and herbaceous material, but this was not possible in some scats. Accordingly, we pooled these as "green vegetation."

Our null hypothesis was that diet did not vary among periods and years. We used two-way analysis of variance (ANOVA) (Kuehl 1994; SAS Institute Inc. 1990) to compare the dry mass percentage of individual food item categories among periods and years. We based post-hoc pairwise comparisons on Fisher's least significant difference (LSD) test (Sokal and Rohlf 1981). To approximate normality, we arcsine square root transformed the aggregate percentage mass data (Korschgen 1980). Differences were considered significant at $P < 0.05$.

Results

During the 1990–1992 field seasons, we collected 1023 scats (373 in 1990, 340 in 1991, and 310 in 1992). The number of scats collected varied somewhat among periods. For example, during the August and September–October periods, no live-trapping was conducted (Obbard and Howe 2008), and fewer scats were found on roads during this period, as some American Black Bears had left the study area on foraging excursions (Obbard and Kolenosky 1994). Of the 1023 scats, we randomly chose 103 for analysis (Tables 1–2).

Amounts of green vegetation differed among months and years (Tables 1–3). During the May and June periods, green vegetation was the major food component ingested; this decreased dramatically during July and August and increased again in September–October. The species of green vegetation that were prevalent, expressed as percentage frequency of occurrence, were clovers (*Trifolium* spp.), Common Dandelion (*Taraxacum officinale*), hawkweeds (*Hieracium* spp.), horse-tails (*Equisetum* spp.), Trembling Aspen, and willows (Table 4). Other items found in high frequency (though not mass) included seeds of Paper Birch, Climbing False Buckwheat (*Fallopia scandens*), and Tufted Vetch (*Vicia cracca*) (Table 4).

The amount of grasses and sedges (Grass category) in scats differed among periods (Tables 1–2), but not among years (Table 3). The main graminoids (Graminae) eaten were Bluejoint Reedgrass (*Calamagrostis canadensis*), Fowl Mannagrass (*Glyceria striata*), and Quackgrass (*Elymus repens*). The primary sedges (Cyperaceae) consisted of Tussock Cottongrass (*Eriophorum vaginatum* ssp. *spissum*), Awl-fruit Sedge (*Carex stipitata*), and various other *Carex* species. Other grasses and sedges found in very small amounts were Fringed

Brome (*Bromus ciliatus*), Common Timothy (*Phleum pratense*), bulrushes (*Scirpus* spp.), Yellow Sedge (*Carex flava*), and other *Carex* species.

Fruits were not prominent in the diet until July, August, and September–October. Early emergent berry species such as blueberries, Bunchberry, Skunk Currant (*Ribes glandulosum*), raspberries, and Wild Sarsaparilla dominated in July (Tables 1–2). Fruits eaten in August were blueberries, Bunchberry, mountain-ashes, Pin Cherry, raspberries, Bristly Sarsaparilla, and Wild Sarsaparilla. The prominent fruit species in September–October scats were blueberries, Bunchberry, raspberries, mountain-ashes, and Pin Cherry. Beaked Hazelnut, the only hard mast species found in the study area, was an important food item in September–October. Squashberry (*Viburnum edule*) was found in only one scat, which was homogeneous for this single food item, thus resulting in a high aggregate percentage mass (Tables 1–2). Alder-leaved Buckthorn (*Rhamnus alnifolia*), Three-leaf Solomon's Seal (*Maianthemum trifolium*), Red-osier Dogwood (*Cornus stolonifera*), serviceberries, and honeysuckles (*Lonicera* spp.) were found in low frequency.

There was considerable variation among years in some food items (Table 3). For example, a significantly greater amount of blueberries was found in scats in August 1991 than in the other two years (Figure 2). Wild Sarsaparilla was in greater abundance in August of 1990 than in the other two years, and mountain-ashes were in greater abundance in August 1992 than in the other two years (Figure 2). Raspberries varied in frequency of occurrence in August among years, but more greatly in dry mass, with dry mass in 1992 being much lower than in the other two years. Bristly Sarsaparilla was abundant in scats from August 1991, but was not

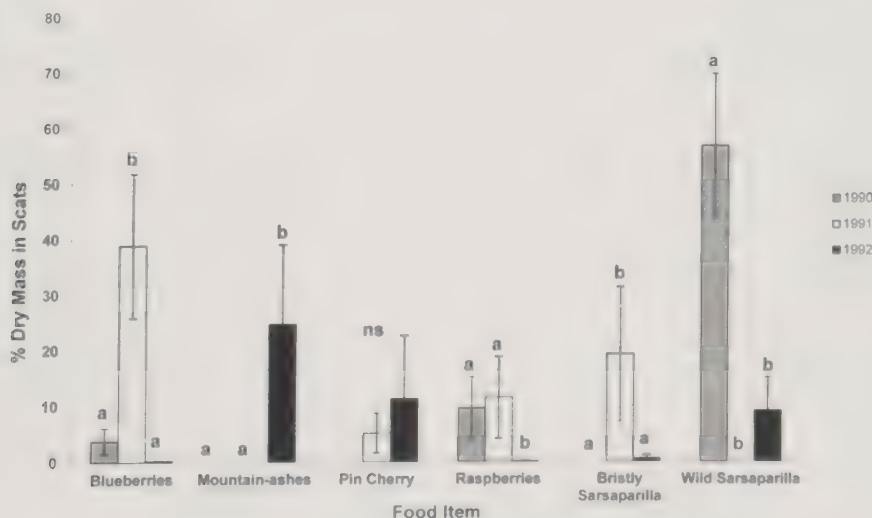


FIGURE 2. Mean percentage dry mass (error bars show standard deviation) of berries that were found in American Black Bear scats ($n = 26$) collected from the Chapleau Crown Game Preserve in August 1990–1992. Different superscripts indicate significant differences ($P \leq 0.05$) between years.

TABLE 1. Frequency of occurrence (%) of food items in American Black Bear (*Ursus americanus*) scats ($n = 103$) collected during five periods from the Chapleau Crown Game Preserve, Ontario, during 1990–1992. – = not detected; nd = no data.

Food item	May			June			July			August			September–October		
	1990 ($n = 6$)	1991 ($n = 7$)	1992 ($n = 6$)	1990 ($n = 10$)	1991 ($n = 7$)	1992 ($n = 9$)	1990 ($n = 6$)	1991 ($n = 6$)	1992 ($n = 6$)	1990 ($n = 9$)	1991 ($n = 10$)	1992 ($n = 7$)	1990 ($n = 7$)	1991 ($n = 0$)	1992 ($n = 7$)
Vegetative Items	–	–	–	–	–	–	–	–	–	–	–	–	86	nd	71
Green vegetation	100	100	100	100	100	100	100	100	100	67	60	100	71	nd	57
Grasses	100	86	100	100	100	100	100	100	100	89	80	100	14	nd	14
Alder-leaved Buckthorn	–	–	–	–	–	–	–	33	–	22	–	14	14	nd	57
Beaked Hazelnut	–	–	–	–	14	–	–	–	–	–	10	14	14	nd	14
Blueberries	17	29	20	–	43	11	83	100	50	78	90	57	14	nd	14
Bristly Black Currant	–	–	–	–	–	–	–	–	–	–	–	–	–	nd	14
Bunchberry	–	–	–	–	–	–	33	33	–	78	30	43	29	nd	43
Common Strawberry	–	–	–	–	14	–	–	–	17	–	–	–	–	nd	–
Honeysuckle	–	–	–	–	–	11	–	–	–	–	–	–	–	nd	14
Mountain-ashes	–	–	–	–	–	–	–	–	–	–	–	43	14	nd	100
Pin Cherry	–	–	–	–	–	–	–	–	–	–	20	14	–	nd	29
Raspberries	–	–	20	10	43	33	33	50	–	78	90	57	29	nd	57
Red-oiser Dogwood	–	–	–	–	–	–	–	–	17	22	–	–	–	nd	–
Serviceberries	–	–	–	–	–	11	17	17	–	11	–	29	–	nd	–
Skunk Currant	–	–	–	–	–	–	17	33	33	22	10	29	–	nd	–
Squashberry	–	–	–	–	–	–	–	–	–	–	–	–	14	nd	–
Bristly Sarsaparilla	–	–	–	–	–	–	–	–	–	–	60	–	–	nd	14
Wild Sarsaparilla	–	14	20	10	29	–	50	83	33	100	20	43	29	nd	14
Three-leaved False	–	–	–	–	–	–	–	–	–	–	–	–	–	nd	–
Solomon's Seal	–	–	–	–	–	–	–	–	–	–	–	14	–	nd	–
Non-Vegetative items	–	–	–	–	–	–	–	–	–	–	–	–	–	nd	–
Ants	67	57	100	90	100	78	100	100	100	89	80	57	29	nd	–
Wasps	–	–	–	10	–	11	17	83	17	78	70	71	57	nd	71
Animal	–	14	–	17	29	11	17	33	17	11	–	43	29	nd	–
Debris	83	100	100	100	100	100	100	100	100	100	90	100	100	nd	100
Unknown	67	43	20	30	100	78	67	100	67	100	80	86	86	nd	29
Other	50	14	40	30	29	56	17	33	17	11	–	57	29	nd	43

TABLE 2. Mean dry mass (g) (SD in parentheses) of food items in American Black Bear (*Ursus americanus*) scats ($n = 103$) collected during five periods from the Chapleau Crown Game Preserve, Ontario, during 1990–1992. – = not detected; nd = no data; 0.0 = trace amount.

Food Item	May			June			July			August			September–October		
	1990 ($n = 6$)	1991 ($n = 7$)	1992 ($n = 6$)	1990 ($n = 10$)	1991 ($n = 7$)	1992 ($n = 9$)	1990 ($n = 6$)	1991 ($n = 6$)	1992 ($n = 6$)	1990 ($n = 9$)	1991 ($n = 10$)	1992 ($n = 7$)	1990 ($n = 7$)	1991 ($n = 0$)	1992 ($n = 7$)
Vegetative Items															
Green vegetation	66.1 (12.7)	47.9 (10.9)	31.3 (6.7)	66.1 (6.2)	53.3 (12.9)	49.6 (9.1)	8.0 (2.3)	2.4 (0.4)	16.0 (8.2)	0.3 (0.1)	1.4 (1.3)	4.0 (3.8)	26.4 (15.4)	nd	11.0 (10.9)
Grass	16.8 (7.5)	17.5 (13.1)	24.2 (9.7)	6.9 (4.4)	3.0 (1.4)	9.5 (4.5)	0.8 (0.1)	0.3 (0.1)	1.9 (0.9)	0.0	0.7 (0.5)	0.7 (0.4)	1.2 (0.8)	nd	2.0 (2.0)
Alder-leaved Buckthorn	–	–	–	–	0.1 (0.1)	–	–	0.0	–	3.1 (2.6)	–	0.0	0.2 (0.2)	nd	0.0
Baked Hazelnut	–	–	–	–	1.3	–	–	–	–	–	1.1 (1.1)	0.2 (0.2)	0.3 (0.3)	nd	13.8 (13.4)
Blueberries	0.0	0.0	0.2 (0.2)	–	0.0	0.0	7.9 (7.4)	15.2 (14.2)	16.8 (14.7)	3.8 (2.3)	38.9 (13.0)	0.2 (0.1)	0.3 (0.3)	nd	13.4 (13.4)
Bristly Black Currant	–	–	–	–	–	–	–	–	–	–	–	–	–	nd	0.0
Bunchberry	–	–	–	–	–	–	0.0	6.0 (5.9)	–	3.0 (1.3)	1.8 (1.7)	1.5 (1.5)	0.0	nd	8.8 (8.5)
Common Strawberry	–	–	–	–	0.0	–	–	–	0.1 (0.1)	–	–	–	–	nd	–
Honeysuckles	–	–	–	–	–	0.0	–	–	–	–	–	–	–	nd	0.1 (0.1)
Mountain-ashes	–	–	–	–	–	–	–	–	–	–	–	24.9 (14.3)	3.4 (3.4)	nd	21.1 (13.0)
Pin Cherry	–	–	–	–	–	–	–	–	–	–	5.2 (3.6)	11.4 (11.4)	–	nd	10.9 (10.2)
Raspberries	–	–	0.2 (0.2)	0.0	0.0	0.0	0.0	1.1 (0.9)	–	9.7 (5.7)	11.6 (7.4)	0.1 (0.1)	0.1 (0.1)	nd	0.2 (0.1)
Red-osier Dogwood	–	–	–	–	–	–	–	–	1.7 (1.7)	0.7 (0.7)	–	–	–	nd	–
Serviceberries	–	–	–	–	–	0.0	0.0	0.0	–	0.0	–	0.0	–	nd	–
Skunk Currant	–	–	–	–	–	–	0.0	11.6 (11.3)	0.2 (0.1)	0.0	1.1 (1.1)	0.0	–	nd	–
Squashberry	–	–	–	–	–	–	–	–	–	–	–	–	11.4 (11.4)	nd	–
Bristly Sarsaparilla	–	–	–	–	–	–	–	–	–	–	19.4 (12.2)	–	–	nd	0.6 (0.6)
Wild Sarsaparilla	–	0.0	0.1 (0.1)	0.0	0.0	–	15.1 (14.2)	9.2 (5.1)	0.5 (0.5)	57.3 (13.0)	0.0	9.2 (6.0)	0.0	nd	0.0
Three-leaved False	–	–	–	–	–	–	–	–	–	–	–	–	–	nd	–
Solomon's Seal	–	–	–	–	–	–	–	–	–	–	–	0.0	–	nd	–
Non-Vegetative items															
Ants	1.2 (1.0)	0.5 (0.4)	0.7 (0.4)	1.3 (0.4)	5.5 (2.2)	4.5 (2.4)	11.8 (3.5)	5.5 (2.4)	5.6 (2.0)	2.1 (1.1)	0.1 (0.1)	0.2 (0.2)	0.2 (0.2)	nd	–
Wasps	–	–	–	0.0	–	0.0	0.2 (0.2)	3.5 (2.6)	0.1 (0.1)	0.8 (0.5)	3.9 (2.9)	0.6 (0.4)	4.0 (2.6)	nd	0.6 (0.6)
Animal	–	0.3 (0.3)	–	0.6 (0.6)	0.1 (0.1)	0.0	0.6 (0.6)	0.1 (0.1)	2.6 (2.6)	1.3 (1.3)	–	11.1 (7.1)	24.9 (16.1)	nd	–
Debris	14.6 (7.8)	33.7 (8.5)	43.0 (9.9)	25.0 (6.5)	35.6 (10.0)	35.6 (8.4)	55.3 (12.2)	43.6 (13.1)	53.0 (10.5)	16.0 (4.8)	14.6 (7.9)	30.3 (8.9)	21.9 (7.9)	nd	17.6 (5.0)
Unknown	1.3 (0.8)	0.3 (0.3)	0.1 (0.1)	0.0	1.1 (0.3)	0.4 (0.3)	0.2 (0.1)	1.6 (0.4)	1.7 (1.2)	1.9 (0.7)	0.4 (0.3)	5.1 (4.4)	5.8 (3.8)	nd	0.0
Other	0.0	0.0	0.3 (0.3)	0.0	0.1 (0.1)	0.3 (0.3)	0.0	0.0	0.0	0.1 (0.1)	–	0.4 (0.3)	0.1 (0.1)	nd	0.0

TABLE 3. Two-way analysis of variance (ANOVA) test statistics (*F* values and *P* values) for comparisons of year (three levels—1990, 1991, 1992) and period (five levels—May, June, July, August, and September–October) main treatment effects, and their interaction (year • period), on dry mass of American Black Bear (*Ursus americanus*) food items from scats (*n* = 103) examined from the Chapleau Crown Game Preserve, Ontario. *P*-values in bold were significant at $\alpha = 0.05$.

Food Item	Year		Period		Year • Period	
	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
Vegetative items						
Green vegetation	3.33	0.040	37.90	0.001	0.73	0.647
Grasses	0.80	0.451	8.51	0.001	0.24	0.975
Alder-leaved Buckthorn	1.33	0.270	1.23	0.303	1.36	0.231
Beaked Hazelnut	0.93	0.397	2.05	0.094	0.83	0.564
Blueberries	4.19	0.018	4.08	0.005	2.15	0.047
Bunchberry	0.03	0.969	2.00	0.101	1.34	0.239
Common Strawberry	0.60	0.549	0.75	0.564	1.46	0.193
Honeysuckles	1.62	0.204	1.13	0.349	0.70	0.671
Mountain-ashes	6.12	0.003	3.32	0.014	2.38	0.028
Pin Cherry	1.56	0.216	1.66	0.167	0.66	0.704
Raspberries	2.92	0.059	6.23	0.001	1.36	0.232
Red-osier Dogwood	0.51	0.600	1.01	0.407	1.40	0.218
Serviceberries	0.15	0.862	1.71	0.155	0.94	0.481
Skunk Currant	2.05	0.135	1.56	0.193	1.16	0.332
Squashberry	0.85	0.432	1.52	0.204	0.84	0.555
Bristly Sarsaparilla	2.30	0.107	1.84	0.128	1.64	0.135
Wild Sarsaparilla	10.71	0.001	14.06	0.001	9.39	0.001
Three-leaved False Solomon's Seal	0.61	0.543	1.38	0.246	0.69	0.684
Non-Vegetative items						
Ants	0.46	0.631	17.25	0.000	1.92	0.075
Wasps	1.51	0.226	4.22	0.004	0.86	0.541
Animal	1.28	0.283	1.77	0.141	2.43	0.025
Debris	1.59	0.211	5.58	0.001	0.97	0.458
Unknown	0.46	0.633	1.41	0.238	3.47	0.003
Other	2.07	0.133	0.28	0.891	1.24	0.290

found in August scats from 1990 or 1992 (it was found in some scats from September–October in 1992).

The mass of ants (Formicidae) in scats varied among periods (Table 3). Ants were found in scats throughout the sampling periods, but were found in very high frequency in scats from June and July each year (Tables 1–2). Scats contained adult ants, pupae, and larvae in association with large amounts of wood chips. The mass of wasps (Vespidae) varied among periods but not among years (Table 3). Wasps were a consistent food source that appeared in scats from June through September–October, but were most prevalent in August (Tables 1–2).

We found significant interactions between year and period for Wild Sarsaparilla, blueberries, mountain-ashes, animal, and the unknown category (Table 3).

Mammal, bird, and fish remains were found in 15 different scats (15% of total) (Table 4). Snowshoe Hare (*Lepus americanus*) (4 scats), American Beaver (*Castor canadensis*) (3 scats), and Moose (*Alces americanus*) (2 scats) were the mammals most often consumed. Unidentifiable bird remains were found in 4 scats. One scat contained remnants of a variety of mammals along with fish scales and bones (Table 4).

The Unknown component consisted of items which could not be identified, either because we found no suit-

able matches or because the items were too small and too well digested to be recognized. The Other category consisted of insects such as beetles (Coleoptera), larvae, roots, and snails. These were likely accidentally ingested, or, in the case of larvae and snails, they may have appeared on the scat after it was deposited.

Discussion

General results of our study are similar to those of other studies of American Black Bear food habits (Tisch 1961; Irwin and Hammond 1985; Holcroft and Herrero 1991; Boileau et al. 1994), in which green vegetation and grasses comprised the bulk of diets in the spring and soft fruits and hard mast became the major constituents of the diet in summer and fall. However, our study highlights the importance of summer soft mast crops to American Black Bears in the boreal forest and shows the great variation that can occur in these crops among years. For example, 1990 was an average year in terms of vegetation emergence and development in our study area, whereas in 1991 and 1992 vegetation emerged early (Usui et al. 2005). Frosts in late May 1992 destroyed most of the flowers on the early-flowering berry species such as Early Lowbush Blueberry and raspberries (Chapleau Station: 25 May 1992 minimum air temperature -4.5°C, 26 May 1992 mini-

TABLE 4. Frequency of occurrence (percentage of scats) of plant matter in American Black Bear (*Ursus americanus*) scats presented in alphabetical order and total number of scats with animal remains, Chapleau Crown Game Preserve, Ontario, 1990–1992. n.d. = no data.

Food item	1990						1991				1992				Total no. scats n = 103	
	September–October						September–October				September–October					
	May n = 6	June n = 10	July n = 6	August n = 9	September October n = 7	May n = 7	June n = 7	July n = 6	August n = 10	September–October n = 0	May n = 5	June n = 9	July n = 6	August n = 7		September October n = 7
Plant material																
Beggarticks (<i>Bidens</i> spp.) (seeds)	–	–	–	–	–	–	–	–	–	n.d.	–	–	–	–	14	1
Canada Thistle (<i>Cirsium arvense</i>) (leaves)	–	10	–	–	–	–	–	33	–	n.d.	–	22	17	–	14	7
Broad-leaved Cattail (<i>Typha latifolia</i>) (root)	–	–	–	–	–	–	–	–	–	n.d.	–	11	–	–	–	1
Canada Lettuce (<i>Lactuca canadensis</i>) (flowers, seeds)	–	–	–	22	–	–	–	17	–	n.d.	–	11	–	14	–	5
(Climbing False Buckwheat (<i>Polygonum scandens</i>) (seeds)	–	–	17	11	–	–	–	–	30	n.d.	–	22	–	14	14	9
Clovers (<i>Trifolium</i> spp.) *	67	70	67	–	43	43	86	33	–	n.d.	50	78	100	14	29	48
Common Dandelion (<i>Taraxacum officinale</i>) *	50	90	–	–	29	71	43	17	–	n.d.	–	67	17	–	–	29
(Creeping Snowberry (<i>Gaultheria procumbens</i>) (leaves)	–	–	17	–	–	–	–	–	–	n.d.	–	11	–	14	–	3
Early Meadow-Rue (<i>Thalictrum dioicum</i>) (leaves)	–	–	–	–	–	14	–	–	–	n.d.	–	–	–	–	–	1
Hawkweeds (<i>Hieracium</i> spp.) *	17	40	33	11	–	57	29	–	–	n.d.	33	33	33	14	–	23
Horsetails (<i>Equisetum</i> spp.)	–	–	–	22	14	–	14	17	–	n.d.	17	33	33	14	–	12
Labrador Tea (<i>Rhododendron groenlandicum</i>) (leaves)	–	–	–	22	14	–	–	33	10	n.d.	–	11	–	–	–	7
Paper Birch (<i>Betula papyrifera</i>) (seeds)	33	10	17	22	14	–	29	17	–	n.d.	–	56	17	29	14	18
Rough Cinquefoil (<i>Potentilla norvegica</i>) (leaf, seed)	17	–	–	–	–	–	–	–	–	n.d.	–	–	–	–	–	1
Spotted Joe Pye Weed (<i>Eutrochium maculatum</i> var. <i>maculatum</i>) (seeds)	–	–	–	–	–	–	–	–	–	n.d.	–	11	–	–	–	1
Trembling Aspen (<i>Populus tremuloides</i>) (buds, leaves)	33	70	17	11	–	57	86	17	–	n.d.	17	56	33	–	–	26
Tufted Vetch (<i>Vicia cracca</i>) (seeds)	–	10	33	33	29	14	–	17	30	n.d.	17	33	–	14	14	18
White Sweet-Clover (<i>Melilotus alba</i>) (seeds)	–	–	–	–	–	–	–	–	10	–	–	–	–	14	–	1
Willows (<i>Salix</i> spp.) (buds, leaves, flowers)	83	10	33	11	–	–	–	–	–	–	83	44	–	14	–	18
Unknown	100	80	100	67	86	100	71	83	50	–	33	89	100	100	71	80
Animal material																
Birds (Aves)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
American Beaver (<i>Castor canadensis</i>)	–	1	–	–	–	–	1	1	–	–	–	–	–	1	–	4
Red Fox (<i>Vulpes vulpes</i>) **	–	–	–	1	2	–	–	–	–	–	–	–	–	–	–	3
Chipmunks (<i>Tamias</i> spp.) **	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Red Squirrel (<i>Tamiasciurus hudsonicus</i>) **	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Muskrat (<i>Ondatra zibethicus</i>) **	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fish (Pisces) **	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mole (Talpidae)	–	–	–	–	–	–	–	–	–	–	–	–	**1	–	–	–
Moose (<i>Alces americanus</i>)	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	2
Snowshoe Hare (<i>Lepus americanus</i>)	–	–	1	–	–	–	–	1	–	–	–	1	**1	–	–	4
Unknown	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1

* leaves, flowers, stems, seeds
** food items found in the same scat

mum air temperature -2.5°C ; Environment Canada 2013) and had a major impact on the berry crop (Usui et al. 2005). Early Lowbush Blueberry fruits were fully ripened in the third week of July 1991, but no blueberry fruits were available until the second week of August in 1992, when Velvet-leaved Blueberry became available. Velvet-leaved Blueberry generally flowers 2–3 weeks after Early Lowbush Blueberry, so it was not affected by the late frost in 1992. Further, a cool summer resulted in later ripening of other berry crops in 1992 (Chapleau Station: average daily temperature in July 1992 was 13.7°C compared to 16.6°C in July 1990 and 16.9°C in July 1991; Environment Canada 2013).

Korschgen (1980) and McLellan and Hovey (1995) suggested that more than two years of data are necessary for food habits studies when annual fluctuations and trends are being described. Results from our study support this view, as they showed distinctly different patterns across three years, particularly in the late summer, when berries were the major food item.

Seasonal variation

Green vegetation was the most abundant food item in American Black Bear diets in May and June, and consisted predominantly of clovers, Common Dandelion, hawkweeds, Trembling Aspen, and willows (Table 4). All of these species have been reported previously (Tisch 1961; Raine and Kansas 1990; Schwartz and Franzmann 1991; Boileau et al. 1994), although with less prevalence than in our study, suggesting that these species are more important spring foods for American Black Bears in the boreal forest. Clovers, Common Dandelion, and hawkweeds were mostly associated with disturbed areas, such as recent clear-cuts, roadsides, and roadside gravel borrow pits, and Trembling Aspen and willows were common in regenerating clear-cuts.

Grasses (Grenfell and Brody 1983; Irwin and Hammond 1985; Schwartz and Franzmann 1991) and horse-tails (Hatler 1972; Raine and Kansas 1990) are the dominant food items reported for spring and early summer foraging periods in other studies. In this study, grasses were found in the majority of scats, but only a few scats contained a homogeneous amount. The proportion of grasses in scats is higher than the proportion of grasses in ingested material, since the high cellulose content results in poor digestibility (Grenfell and Brody 1983), whereas succulent forbs are more easily digested. Nevertheless, in our study, grasses were exploited throughout the spring, summer, and fall foraging periods.

Ants were both frequent and abundant in scats during June and July and formed a large proportion of the diet before the onset of the berry season, a pattern also reported by others (Irwin and Hammond 1985; Holcroft and Herrero 1991; Kasbohm et al. 1995; Noyce et al. 1997). Because of the chitinous exoskeleton of ants, the digestibility of adult ants is likely limited. This can introduce bias into scat studies since

the proportion of adult ants in scats is likely higher than the proportion in ingested material (compared to larvae, which are presumably highly digestible) (Hatler 1972; Landers et al. 1979; Boileau et al. 1994). Larvae and pupae would be expected to be the target of ant nest raiding due to their high energy and protein content and high digestibility (Noyce et al. 1997). Wasps increased in frequency in scats about the time that ants were declining in frequency in July and August. Other studies have reported wasps to be a component of the diet in late summer or fall (Hatler 1972; Irwin and Hammond 1985; Holcroft and Herrero 1991).

Mammal, fish, and bird remains were found in 15% of scats in this study. The most common species were Snowshoe Hare, American Beaver, and Moose, similar to the pattern reported by Holcroft and Herrero (1991) and Smith et al. (1994). Animal matter was found in variable amounts and frequency throughout the foraging period, although, unlike other studies (e.g., Schwartz and Franzmann 1991), we did not detect coincidental consumption of Moose calves during the calving season. Schwartz and Franzmann (1991) observed radio-collared calves being killed by American Black Bears, but the low frequency of occurrence of Moose remains in scats in their study confirms the high digestibility of animal matter (Gamberg and Atkinson 1988). The amount of vertebrate remains left in scats likely underestimates the occurrence of these food items in the diet (Putman 1984; Pritchard and Robbins 1990) due to their high digestibility. As such, bone and hair are typically the only components remaining in scats, although these too may be substantially degraded (Gamberg and Atkinson 1988). In addition, American Black Bears typically remove the hide of ungulate prey prior to consumption (Austin et al. 1994), so there would be even less likelihood of finding hairs from young Moose calves in the scats of American Black Bears.

There is anecdotal evidence that American Black Bears in the study area prey on Moose calves (Obbard et al. 2000) and even on adult Moose (Austin et al. 1994). However, it is unknown how commonly such events occur. By comparison, American Black Bears preyed on 11.4% (5 of 44) of radio-collared Moose calves in a study in Algonquin Provincial Park (Patterson et al. 2013), a protected area with American Black Bear density similar to that in the Chapleau Crown Game Preserve (Howe et al. 2013). Dew claws of Moose calves and other remains were occasionally observed in scats of live-trapped American Black Bears during the current study (MEO, unpublished data); however, under the protocol of our study these particular scats were not randomly selected for analysis. More intensive sampling may be required to detect consumption of Moose calves by scat analysis.

The high incidence of American Beaver remains in fall scats suggests that American Beavers may be more vulnerable to predation by American Black Bears at

this time, perhaps because American Beavers are harvesting winter food supplies and building food piles (Novak 1987). One scat contained remains of a variety of mammal species as well as fish scales and bones. It is possible that an American Black Bear ingested part or all of a Red Fox (*Vulpes vulpes*) or other small carnivore that had remnants of the various prey in its own gut contents.

Spawning runs of White Sucker (*Catostomus commersonii*) were visited by American Black Bears in the study area in spring each year (ca. 15–30 May) (MEO, unpublished data). Some American Black Bears congregated at these creeks, and spawning fish were apparently a substantial food source, as various components (head, tail, lateral muscle, gut, and combinations of these) were missing from carcasses found adjacent to the creeks (DAR, personal observation). However, not all American Black Bears had such creeks within their home ranges, and no fish remains were found in the scats, which were collected at the time and randomly selected for analysis. It appears that our sampling regime was adequate to describe consumption patterns of most food items, especially the important fruit crops, but was insufficient to detect rarely consumed or seasonally highly restricted food items.

The peak of the soft mast season in scats was in August, following the increase of early maturing species such as strawberries (*Fragaria* spp.), Skunk Currant, Wild Sarsaparilla, raspberries, blueberries, and serviceberries in July and the persistence of some species (raspberries, blueberries) and appearance of later maturing species, such as Alder-leaved Buckthorn, Bunchberry, Pin Cherry, Red-osier Dogwood, and Bristly Sarsaparilla. Later maturing species, such as Beaked Hazelnut, Squashberry, and mountain-ashes, were found in scats in September and October.

Variation among years

We showed that American Black Bear food habits determined by scat analysis were similar during the spring season over the three years but differed during the summer and fall seasons. This suggests that spring foods in the boreal forest do not differ greatly in abundance among years and so are predictable. In contrast, summer and fall foods vary greatly in abundance among years, and their abundance likely cannot be predicted by American Black Bears.

The breeding season for American Black Bears in Ontario mainly occurs before summer berry crops are available (Kolenosky 1990), and American Black Bears exhibit delayed implantation (Hamlett 1935), meaning that female American Black Bears that are available to mate are pregnant prior to the appearance of summer and fall food crops (even though blastocysts have not implanted). If females do not gain sufficient body mass prior to late fall, implantation does not occur, and those females do not produce a litter; this can affect lifetime reproductive success. As a result, the energetic demands of reproduction during years of food failure can result

in adult female American Black Bears looking for anthropogenic sources of food and becoming more prone to come into conflict with humans (Howe et al. 2010).

The greatest variation in amount and frequency of occurrence of berry species among years occurred in the August and September–October periods. There was a significant interaction effect among period and year for blueberries, Wild Sarsaparilla, and mountain-ashes. For example, blueberries were fully ripened in early July in 1990, not until the third week of July in 1991, and not until the second week of August in 1992. The berries of mountain-ashes were significantly more abundant than other berry crops in August 1992, whereas blueberries were significantly more abundant in 1991 and Wild Sarsaparilla was more abundant in 1990. The increased availability of the berries of mountain-ashes in 1992 may have compensated for the loss of the Early Lowbush Blueberry crop due to the killing frost which seriously damaged the flowers in the spring that year. The later flowering species, Velvet-leaved Blueberry, was little affected by the late frost and was the species available by mid-August that year.

The variation in abundance of berry species in the September–October period suggests that Beaked Hazelnut, Bunchberry, mountain-ashes, and Pin Cherry were all exploited to a greater extent in 1992 than in 1990 or 1991, further emphasizing how the availability of food crops for American Black Bears can vary among years, that other food crops may compensate if one food crop fails, and emphasizing that American Black Bears must be adaptable to be able to forage opportunistically. Fruit production in species such as mountain-ashes and Pin Cherry is strongly influenced by fruit production in the prior year, often resulting in an alternating pattern of high and low fruit abundance in consecutive years (Howe et al. 2012), again emphasizing that American Black Bears must be adaptable and forage opportunistically.

Two scenarios have been proposed to explain the effect of food crops on American Black Bear populations. The first is that berry use is limited to a major crop that ultimately regulates population recruitment rates (Jonkel and Cowan 1971; Landers et al. 1979; Beeman and Pelton 1980; Rogers 1987; Elowe and Dodge 1989). The alternative explanation is that American Black Bears use a variety of major berry and mast crops, and switch to alternate foods during times of crop failure (Kasbohm et al. 1996). Results of this study suggest that American Black Bears in the boreal forest will switch to alternate foods when a certain crop fails.

A diversity of soft mast producing species can promote stability if different species are productive in different years (Garshelis and Noyce 2008), and a greater overall diversity of mast species can provide demographic stability (Benson and Chamberlain 2006). However, a long-term demographic study of the population of American Black Bears in the Chapleau Crown

Game Preserve showed that cub survival was lower during years of food shortages (such as 1992) and litter production rate was lower in years immediately following food shortages (Obbard and Howe 2008). Therefore, in the boreal forest zone of Ontario, where few alternate food crops are available and there can be considerable annual variation in blueberry production (Usui et al. 2005), American Black Bears may not always be able to compensate for the loss of the blueberry crop. This could occur, for example, if a failure of the blueberry crop happened to coincide with a low production year for alternate crops such as Pin Cherry and mountain-ashes. Understanding how summer food items vary in timing and abundance can help wildlife managers better understand the origins of patterns of human–bear conflicts in the boreal forest, and can provide insights into demographic patterns and variation in harvest levels of American Black Bears and population structure. Monitoring the abundance of important food species for American Black Bears on an annual basis would provide the information necessary to test hypotheses generated by these relationships.

Forestry practices in the boreal forest can have a positive effect on the abundance of foods consumed by American Black Bears, because these species increase in abundance in young regenerating forest stands (Brodeur et al. 2008). Early successional areas containing species such as clovers, Common Dandelion, Trembling Aspen, and willows are important foraging areas for American Black Bears in the boreal forest in the spring. In addition, open areas created by wildfire or timber harvesting, especially where Jack Pine is predominant in the overstory, are important foraging areas in summer, when American Black Bears feed on species such as blueberries, serviceberries, and Bristly Sarsaparilla. Because the abundance of such food items varies among years and our study showed that they are important food items in the diet of American Black Bears in the boreal forest, cutover areas or regenerating burns should be protected from the application of herbicides, which can cause a major reduction in fruit production by species such as *Vaccinium* (Moola et al. 1998).

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Relative Abundance of the Prairie Long-tailed Weasel (*Mustela frenata longicauda*) in Southwestern Alberta

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Prairie Long-tailed Weasels (*Mustela frenata longicauda*) were live-trapped during fall 2005, 2006, and 2007 at Pine Coulee Reservoir and during fall 2005, 2008, and 2010 at Twin Valley Reservoir in southwestern Alberta. Our objective was to estimate the relative abundance of the Long-tailed Weasel and to estimate the relative abundance of small mammal prey. Body size and capture rates are reported for Long-tailed Weasels, and we report capture rates of small mammals. Annual capture rates for Long-tailed Weasels at Pine Coulee Reservoir were 0.44, 0.41, and 0.50 individuals per 100 corrected trap-nights (0.42, 0.38, and 0.48 individuals/100 trap-nights) in 2005, 2006, and 2007, respectively. No Long-tailed Weasels were captured at Twin Valley Reservoir. The probability of capturing zero Long-tailed Weasels at Twin Valley Reservoir was very low, assuming a true capture probability equivalent to that observed at Pine Coulee Reservoir. Deer Mice (*Peromyscus maniculatus*) were the most abundant small mammals captured in both project areas. Few shrews (*Sorex* spp.) and voles (*Microtus* spp.) were captured in either area.

Key Words: *Mustela frenata longicauda*; Prairie Long-tailed Weasel; capture rate; capture probability; relative abundance; *Peromyscus maniculatus*; Deer Mouse; *Sorex*; shrew; *Microtus*; vole; Alberta

Prairie Long-tailed Weasels (*Mustela frenata longicauda*) are known to exist across two thirds of Alberta in semi-urban areas, rural and agricultural areas, grasslands, parklands, the foothills of the Rocky Mountains, and montane forests (Smith 1993). Proulx and Drescher (1993) reported that the Long-tailed Weasel was present in the central and southern regions of the province, as reported in earlier decades (Soper 1964). However, the ecology of the Long-tailed Weasel in Alberta is poorly understood, as is generally true for this species across its range (Gehring and Swihart 2004; Richter and Schaubert 2006; Hajduk 2008). The species is currently designated as May Be At Risk in Alberta (Alberta Sustainable Resource Development 2010*).

We investigated the relative abundance of the Long-tailed Weasel on mitigation land surrounding two reservoirs in southern Alberta, the Pine Coulee Reservoir and the Twin Valley Reservoir, following the completion of the construction of the reservoirs. We also estimated the relative abundance of small mammals on these two mitigation sites in order to investigate the prey base. Mitigation land is a reserve of public land surrounding each water management project, intended to replace habitat lost and altered as a result of project development. Our overall goal was to determine whether Long-tailed Weasels were present at mitigation sites and to determine their relative abundance.

Study Areas

Pine Coulee Reservoir (50°7'N, 113°44'W) and Twin Valley Reservoir (50°14'N, 113°24'W) in southwestern Alberta are separated by about 30 km (Figure 1). Pine

Coulee Reservoir is an off-stream reservoir (elevation 1052.5 m; 50 600 m³ at full supply level; completed in 2000) which lies in the Foothills Fescue Natural Subregion, the highest elevation grassland sub-region in the province (Natural Regions Committee 2006*). Soils in the Foothills Fescue Natural Subregion are primarily Orthic Black Chernozem, reflecting moist, cool conditions. Reference vegetation in this area is Mountain Rough Fescue (*Festuca campestris*) and Idaho Fescue (*Festuca idahoensis*) with a diverse forb component.

Twin Valley Reservoir is an on-stream reservoir (elevation 964.5 m; 60 700 m³ at full supply level; completed in 2004) which lies within the drier and colder Mixedgrass Natural Subregion (Natural Regions Committee 2006*). Soils in this subregion are predominantly Orthic Dark Brown Chernozem, and reference vegetation is Blue Grama (*Bouteloua gracilis*), Needle-and-Thread (*Hesperostipa comata* subsp. *comata*), and Northern Wheat Grass (*Agropyron dasystachyum*).

Methods

We conducted live trapping during the fall of 2005 at both Pine Coulee Reservoir and Twin Valley Reservoir (Table 1). Based on success at Pine Coulee Reservoir but not at Twin Valley Reservoir, we returned to Pine Coulee Reservoir with an expanded effort during fall 2006 and 2007. During fall 2008 and 2010, we returned to Twin Valley Reservoir with an expanded trapping effort. During 2010, we added 16 baited track tunnels and 8 live traps in a trapline along a fence separating mitigation land from cropland at Twin Valley Reservoir (Table 1).

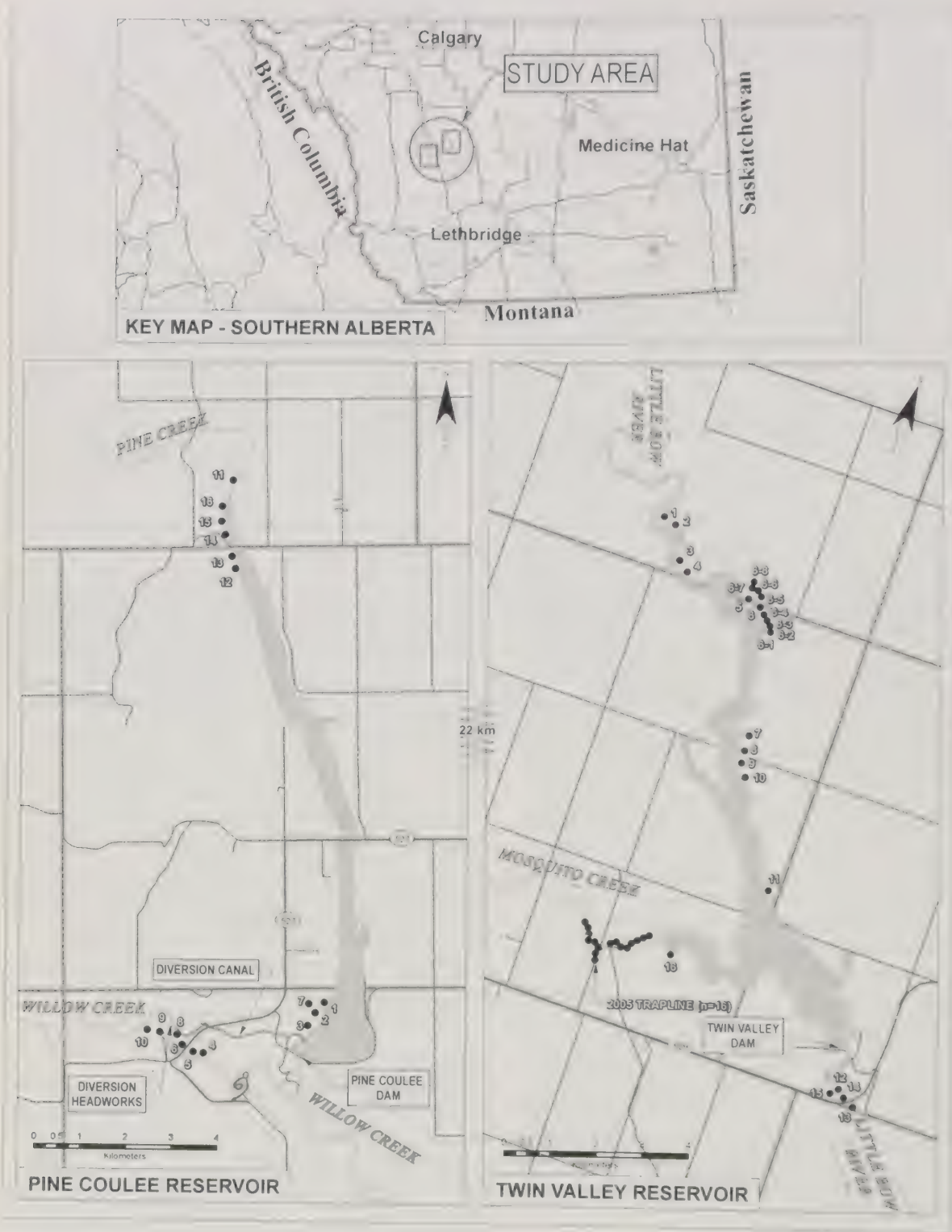


FIGURE 1. Pine Coulee project area (left) showing 16 trapping locations as operated between mid-October and late October 2007, and Twin Valley project area (right) showing 16 trapping locations and trapline as operated between mid-October and late October 2010.

TABLE 1. Prairie Long-tailed Weasel (*Mustela frenata longicauda*) trapping dates and effort (trap nights and corrected trap nights) in southwestern Alberta at the Pine Coulee Reservoir project area in 2005, 2006, and 2007 and at the Twin Valley Reservoir project area in 2005, 2008, and 2010.

Year	Pine Coulee Reservoir		Twin Valley Reservoir	
	Trapping dates	Trapping effort	Trapping dates	Trapping effort
2005	1 to 5 November	238 trap-nights (189 corrected trap-nights) (12 trap grids with a total of 48 traps)	8 to 12 November	200 trap-nights (160 corrected trap-nights) (8 trap grids with a total of 32 traps and 16 traps in trapline)
2006	12 to 24 October	752 trap-nights (626 corrected trap-nights) (15 trap grids with a total of 60 traps)	No fieldwork	
2007	10 to 22 October	794 trap-nights (716 corrected trap-nights) (16 trap grids with a total of 64 traps)	No fieldwork	
2008		No fieldwork	15 to 27 October	789 trap-nights (682 corrected trap-nights) (16 trap grids with a total of 64 traps)
2010		No fieldwork	15 to 27 October	927 trap-nights (787 corrected trap-nights) (16 trap grids with a total of 64 traps and 8 traps in trapline)

Trapping and handling of Long-tailed Weasels

We used Tru-Catch live traps constructed with a wire mesh steel frame (Tru-Catch Traps, Belle Fourche, South Dakota). Two trap sizes were used: Model #18 (46 cm × 15 cm × 18 cm) and Model #24 (61 cm × 20 cm × 23 cm). Trapped areas were chosen *a priori* from the largest contiguous tracts of available mitigation land, subject to the requirement for a wide distribution of traps but constrained by the need for reasonable access. Live traps were set out in a four-trap grid configuration, with 141 m between traps. At a few locations, traps were set closer to accommodate the edge of the reservoir or the edge of a pasture that contained cattle.

A single slice of commercial bacon was used for bait and food (25–30 g per slice) (Simms 1979; Robitaille and Raymond 1995). Bacon has a high fat and salt content, it is aromatic (mustelids have an acute sense of smell) (Merritt 2010), it doesn’t spoil quickly, and it presents no infection-related health concerns to humans or wildlife (Schlexer 2008). Thinsulate microfibre (15 cm × 18 cm) was placed in each live trap for bedding material.

Traps were checked daily, and regular maintenance was performed to maintain a cover of grass and woody material over each live trap, to adjust the bedding material, and to resupply bait. The number of trap-nights was corrected (corrected trap-nights) for traps sprung for any reason, following advice of King (1989), and a few occasions when traps were rendered inoperable by freezing rain (5 traps on 2 November 2005 and 10 traps on 17 October 2006, both at Pine Coulee Reservoir).

We also provide relative abundance based on total (uncorrected) trap-nights. Long-tailed Weasels were

released from live traps into a capture net, and the net was twisted around the weasel for restraint. Body length was measured from the tip of the nose to the base of the tail using a steel pocket tape measure. The tail was measured from the body to the tip. Body weight was measured with an Avinet 1.0-kg spring scale (accurate to within 2 g) (Avinet, Dryden, New York). Each Long-tailed Weasel was individually marked with red hair dye. The sex of the Long-tailed Weasels captured in 2007 was determined by visual inspection of the inguinal region (anal–genital separation), but this was not attempted during earlier captures. Long-tailed Weasels were released at the capture site. A Research Permit and Collection Licence was issued by Alberta Sustainable Resource Development.

Traplines and track tunnels at Twin Valley Reservoir

In 2005, in addition to live trap grids, 16 identical live traps were placed in linear sequence at 141-m intervals along the north bank of Mosquito Creek entering Twin Valley Reservoir (Table 1). This site was chosen based on a location report of a Long-tailed Weasel by Golder Associates (1995*). In 2010, in addition to live trap grids, 8 live traps were placed in linear sequence at 141-m intervals along a fenceline separating mitigation land from cropland at Twin Valley Reservoir near a chance observation of a Long-tailed Weasel in wheat stubble during fall 2008.

Track tunnels specifically designed for detection of weasels (60 cm × 10 cm × 10 cm) were deployed at Twin Valley Reservoir in 2010 as an additional detection device (King and Edgar 1977; Dilks et al. 1996). A track tunnel (*n* = 16) was randomly assigned to one of the live traps within each of the 16 trap grids, offset from the live trap by 10 m in a clockwise direction.

TABLE 2. Capture rates of Prairie Long-tailed Weasels (*Mustela frenata longicauda*) at Pine Coulee Reservoir during three consecutive years of fall live trapping, southwestern Alberta (trap-nights and corrected trap-nights).

Trapping dates	Number of individuals captured	Capture rate (number/100 corrected trap-nights)	Capture rate (number/100 trap-nights)	Mean number of individuals captured/grid
1 to 5 November 2005	1	0.44	0.42	0.08
12 to 24 October 2006	3	0.41	0.38	0.20
10 to 22 October 2007	4	0.50	0.48	0.24

Track cards were inked in the centre with a 10 cm × 10 cm square of ink that surrounded half a slice of bacon. Track cards were inspected daily for tracks and bait was replenished.

Trapping small mammals

A Victor mouse snap trap (Woodstream, Lititz, Pennsylvania, model no. M150CAN) was offset from each live trap by 10 m, to capture mice, voles, and shrews. Snap traps were baited with peanut butter or peanut butter mixed with instant oat flakes (Beer 1964; Patric 1970) and replenished daily. We report small mammal capture rates on the basis of total number of trap-nights adjusted for lost traps, and we report corrected trap-nights (Nelson and Clark 1973). *F* tests for variance and paired or non-paired *t* tests, as indicated, were conducted using Excel 2003.

Results

Eight (8) Long-tailed Weasels were captured at Pine Coulee Reservoir (Table 2): one in 2005, three in 2006, and four in 2007. No Long-tailed Weasels were captured at Twin Valley Reservoir. At Pine Coulee Reservoir, Long-tailed Weasels were captured on six different trap grids (eight different individual trap sites) in three different locations around the reservoir: the riparian zone of Willow Creek, native pasture on the floodplain terrace adjacent to Willow Creek, dense non-native grassland at the edge of heavily grazed pasture adjacent (<100 m) to a constructed wetland, and in native grassland/shrub with a mixture of agronomic species adjacent to the reservoir.

Long-tailed Weasel body measurements

The two females captured on 14 and 16 October at Pine Coulee Reservoir trap site 2E, #1-07 and #2-07, measured 38 cm total body length (body and tail) and 15 cm tail length, and were 170 g and 175 g, respectively. The male captured on 17 October 2007 at Pine Coulee Reservoir trap site 4E, #3-07, was 45 cm total body length and 19 cm tail length, and weighed 270 g. The male captured on 22 October 2007 at Pine Coulee Reservoir site 3E, #4-07, measured 41 cm total body length and 15 cm tail length, and weighed 245 g. The largest Long-tailed Weasel we captured was #3-06, on 23 October 2006 at Pine Coulee Reservoir site 11S. He measured 44 cm total body length and 16.5 cm tail length, and weighed 300 g. Smith (1993) reported the average length for adult females as 37.9 cm and the

average length for adult males as 43.8 cm. The range of live weights for adult females in Alberta was 154.3 g to 242.6 g (*n* = 11) and for adult males in Alberta was 242.3 g to 423.7 g (*n* = 20) (Smith 1993).

Long-tailed Weasel capture rates at Pine Coulee Reservoir

The capture rate of individuals was similar between years: 0.44/100 corrected trap-nights (0.42/100 trap-nights) in 2005, 0.41/100 corrected trap-nights (0.38/100 trap-nights) in 2006, and 0.50/100 corrected trap-nights (0.48/100 trap-nights) in 2007 (Table 2). The probability of capture per grid was 8.3% in 2005 (a Long-tailed Weasel was captured on 1 of 12 grids), 13.3% in 2006 (Long-tailed Weasels were captured on 2 of 15 grids), and 18.8% during 2007 (Long-tailed Weasels were captured on 3 of 16 grids). The probability increased to 35.7% (5 of 14 grids) when data from trap grids common to 2006 and 2007 were combined. This demonstrates the advantage of trapping for more than one year to gain an understanding of spatial distribution; an advantage also accrues respecting comparison of Long-tailed Weasels between the two project areas.

Long-tailed Weasels at Twin Valley Reservoir

No Long-tailed Weasels were captured at Twin Valley Reservoir, despite a known presence adjacent to the project area that was revealed by a chance observation of a Long-tailed Weasel on 17 October 2008 at a burrow in wheat stubble on day 3 of the 13-day trapping session. The chance observation was 295 m from the closest live trap near the edge of mitigation land.

We estimated the probability of not capturing a Long-tailed Weasel at Twin Valley Reservoir over two non-consecutive years (2008 and 2010) and assuming the same capture probability as at Pine Coulee Reservoir. Using a modification of Kery (2002), the probability of zero captures using 16 grids trapped for two years is *P* = 0.09%. This low estimate of Type II Error (relevant to a conclusion that Long-tailed Weasels were not present when they were present at the frequency observed at Pine Coulee Reservoir) demonstrates the advantages of multiple years of sampling to better understand the level of uncertainty of presence/not detected for a relatively rare and elusive species.

Small mammal capture rate

At both mitigation sites, Deer Mice (*Peromyscus maniculatus*), shrews (*Sorex* spp.), and voles (*Microtus*

TABLE 3. Capture rate of small mammals at the Pine Coulee Reservoir and the Twin Reservoir Valley project areas on 4-trap grids and traplines, southwestern Alberta, showing trap-nights (corrected trap-nights in parentheses).

Project area and year	Trapping dates and configuration	No. of trap-nights	Species	No. captured	Capture rate/100 trap-nights
Pine Coulee 2005	1 to 5 November 12 4-trap grids	238 (189)	Deer Mouse	68	28.6 (36.0)
			Shrew spp.	3	1.3 (1.6)
			Vole spp.	0	0
			Total	71	29.8 (37.6)
Pine Coulee 2006	12 to 24 October 15 4-trap grids	752 (625.5)	Deer Mouse	151	20.1 (24.1)
			Shrew spp.	3	0.4 (0.5)
			Vole spp.	10	1.3 (1.6)
			Total	164	21.8 (26.2)
Pine Coulee 2007	10 to 22 October 16 4-trap grids	794 (715.5)	Deer Mouse	104	13.1 (14.5)
			Shrew spp.	2	0.2 (0.3)
			Vole spp.	2	0.2 (0.3)
			Total	108	13.6 (15.1)
Twin Valley 2005	8 to 12 November 8 4-trap grids	138 (116)	Deer Mouse	34	24.6 (29.3)
			Shrew spp.	2	1.4 (1.7)
			Vole spp.	1	0.7 (0.9)
			Total	37	26.8 (31.9)
Twin Valley 2008	Mosquito Creek trapline 15 to 27 October 16 4-trap grids	789 (682)	Deer Mouse	27	43.5 (61.4)
			Deer Mouse	103	13.1 (15.1)
			Shrew spp.	52	6.6 (7.7)
			Meadow Vole	15	1.9 (2.2)
			Total	170	21.5 (24.9)
Twin Valley 2010	15 to 27 October 16 4-trap grids	825 (717.5)	Deer Mouse	101	12.2 (14.1)
			Shrew spp.	52	6.3 (7.2)
			Meadow Vole	21	2.5 (2.9)
			Total	174	21.1 (24.2)
	Agriculture edge trapline	102 (69.5)	Deer Mouse	51	50.0 (73.4)
			Shrew spp.	2	2.0 (2.9)
			Meadow Vole	1	1.0 (1.4)
			Total	54	52.9 (77.7)

spp.) were captured. In the composite sample trapped for all years (2005–2007) at Pine Coulee Reservoir, 94% were Deer Mice, while shrews and voles were captured in nearly equal small percentages (2% and 4%, respectively). At Twin Valley Reservoir, excluding trap line captures, 62% of captures were Deer Mice, while 28% were shrews and 10% were voles. We did not individually identifying the shrews and voles in all years; however, the species that could be expected in these study areas include Cinereus Shrew (Masked Shrew) (*Sorex cinereus*), Prairie Shrew (*Sorex haydeni*), Dusky Shrew (*Sorex monticolus*), Meadow Vole (*Microtus pennsylvanicus*), and Sagebrush Vole (*Lemmiscus curtatus*) (Smith 1993).

The highest capture rate for Deer Mice was at Twin Valley Reservoir, along the fenceline separating the grain crop from mitigation land (50.0/100 trap-nights) (73.4/100 corrected trap-nights) and within the riparian zone of Mosquito Creek in 2005 (43.5/100 trap-nights) (61.4/100 corrected trap-nights) (Table 3). The capture rate along traplines in these two ecotones was 3 to 4 times higher than the capture rates on grids within tracts of relatively homogenous habitat.

On live trap grids, the capture rate of Deer Mice was highest during 2005 in both project areas, but somewhat higher at Pine Coulee Reservoir than at Twin Valley Reservoir (28.6/100 trap-nights (36.0/100 corrected trap-nights) at Pine Coulee Reservoir and 24.6/100 trap-nights (29.3/100 corrected trap-nights) at Twin Valley Reservoir) (Table 3).

During more intensive trapping effort at Pine Coulee Reservoir in 2006 and 2007 and at Twin Valley Reservoir in 2008 and 2010, the relative abundance of Deer Mice in both areas did not differ significantly between years (20.1/100 trap-nights (24.1/100 corrected trap-nights) versus 13.1/100 trap-nights (14.5/100 corrected trap-nights)) at Pine Coulee Reservoir ($F_{55,55} = 0.90$, $P = 0.35$, $t_{110} = 1.82$, $P = 0.07$); and 13.1/100 trap-nights (15.1/100 corrected trap-nights) versus 12.2/100 trap-nights (14.1/100 corrected trap-nights)) at Twin Valley Reservoir, t_{63} (paired) = 0.42, $P = 0.68$).

In temperate ecosystems, small mammals have been identified as universal prey, captured by virtually all carnivores and birds of prey (Gliwicz and Taylor 2002). Small mammals are important prey for the Long-tailed Weasel (Quick 1951; Simms 1979; Fagerstone 1999).

However, larger prey species of the Long-tailed Weasel, such as Richardson's Ground Squirrel (*Urocitellus richardsonii*) (formerly *Spermophilus richardsonii*) and the Northern Pocket Gopher (*Thomomys talpoides*), were not sampled.

Discussion

We provide the first estimates of relative abundance of the Long-tailed Weasel in Alberta.

The relative abundance of Long-tailed Weasels on mitigation land at Pine Coulee Reservoir in southwestern Alberta was similar to, if not somewhat higher than, most other areas in Canada (Manitoba and Ontario) and the United States (Illinois and Indiana). Simms (1979) estimated the relative abundance of Long-tailed Weasels in four areas of southern Ontario using individual captures per 100 trap-nights: 1.03/100 trap-nights on a 100-m trap grid in Point Pelee National Park in southwestern Ontario; 0.06/100 trap-nights on a 100-m trap grid in the Boyd Conservation Area and 0.28/100 trap-nights on a 100-m trapline in Duffin's Creek Conservation Area; and 0.08/100 trap-nights on a 100-m trapline in Algonquin Provincial Park in south-central Ontario. In southern Manitoba, Gamble (1980) reported 22 individuals captured during 21 275 trap-nights, for a relative abundance of 0.10/100 trap-nights (clustered trap arrangement using a variety of baits). Gehring and Swihart (2004) reported a relative abundance of 0.40 Long-tailed Weasels captured per 100 trap-nights (22 captures of 17 Long-tailed Weasels during 4 256 trap-nights) in an agricultural landscape of west-central Indiana. Hajduk (2008) reported a relative abundance of 0.25 captures/100 trap-nights (0.23 individuals/100 trap-nights) in Pyramid State Park, Illinois.

Our results confirm that mitigation land surrounding Pine Coulee Reservoir provides suitable habitat for the Long-tailed Weasel. Our results also suggest that the Long-tailed Weasel population at Pine Coulee Reservoir remained stable during those years. If the population was stable, it also indicates the methodology was robust and provides support for our method as a means of long-term monitoring of relative abundance. Although the total length body measurements at Pine Coulee correspond to averages reported for Alberta by Smith (1993), the live weights that we obtained were at the lower end of the range reported for Alberta.

No Long-tailed Weasels were captured on mitigation land surrounding Twin Valley Reservoir. We conclude that Long-tailed Weasels may not be resident on the Twin Valley Reservoir mitigation lands. If Long-tailed Weasels are resident there, they are less widely distributed and/or occur at lower density than at Pine Coulee Reservoir. This difference may be due to differences in one or more ecosystem components between the two project areas, and this suggests a fruitful avenue for further study.

If Long-tailed Weasels are present at Twin Valley Reservoir, they proved to be elusive and appeared to be considerably less abundant than at Pine Coulee Reservoir. The relative abundance of Deer Mice, shrews, and voles appeared to be similar at the two mitigation sites. This suggests that the relative abundance of small mammal prey that we examined did not explain the difference in relative abundance of Long-tailed Weasels.

We speculate that differences between the two mitigation sites with respect to abundance of large mammal prey, such as Richardson's Ground Squirrels and Northern Pocket Gophers, may have contributed to the observed difference in the abundance of Long-tailed Weasels. Also, differences in soil types, habitat types, land uses (cultivation and grazing history), and land use in the surrounding landscape were not measured at either mitigation site.

The basic ecological requirements of Long-tailed Weasels are food and cover resources, but Long-tailed Weasel populations also need space and protective corridors to allow for movement through and across the landscape. These unmeasured components suggest avenues for further study that may help explain differences in Long-tailed Weasel abundance in these two areas of southwestern Alberta and provide further insight into their ecology in general.

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Trumpeter Swan (*Cygnus buccinator*) Behaviour, Interactions with Snapping Turtles (*Chelydra serpentina*), and Their Pleistocene History

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Lumsden, Harry G. 2013. Trumpeter Swan (*Cygnus buccinator*) behaviour, interactions with Snapping Turtles (*Chelydra serpentina*), and their Pleistocene history. *Canadian Field-Naturalist* 127(2): 138–145.

Snapping Turtles (*Chelydra serpentina*) prey on and injure Trumpeter Swan (*Cygnus buccinator*) cygnets. Adult Trumpeter Swans stamp on and attack turtles, and this sometimes saves the lives of cygnets. Stamping behaviour, duetting, clamouring, and mobbing are directed at predators. The stamping behaviour may be derived from the water treading display. During the Pleistocene ice sheet maxima, all Trumpeter Swans east of the Rockies nested within the range of the Snapping Turtle. Snapping Turtle predation may have selected for the stamping behaviour.

Key Words: Snapping Turtle; *Chelydra serpentina*; predation; Trumpeter Swan; *Cygnus buccinator*; injuries, stamping attack; duetting; clamouring; mobbing behaviour; water treading display; Pleistocene distribution; Wisconsin glaciation; Yellow-stone glacier; Ontario

There are two Trumpeter Swan (*Cygnus buccinator*) populations in North America. Studies of mitochondrial DNA by Oyler-McCance et al. (2007) showed that the Pacific coast population breeding in Alaska and west of the Rocky Mountains differ significantly from the remnant population breeding in a small area in and east of the Rocky Mountains and those centred in the Grand Prairie region of Alberta. This paper deals mostly with the Rocky Mountain population.

Snapping Turtle (*Chelydra serpentina*) predation on waterfowl and shorebirds was recorded long ago (Alexander 1943; Lagler 1943; Coulter 1957; Pryor 1996). Willey and Halla (1972) thought that Snapping Turtles were the primary source of mortality of Mute Swan (*Cygnus olor*) cygnets in Rhode Island. Lumsden (1986) reported on the loss to a Snapping Turtle of Trumpeter Swan cygnets cross-fostered by Mute Swan parents. Abel (1992) attributed the deaths of Trumpeter Swan cygnets cross-fostered by Mute Swans in Wisconsin to Snapping Turtles. At close range, Abel (1992) also witnessed the circumstances surrounding Snapping Turtle attacks on Trumpeter Swan cygnets imprinted on life-sized swan decoys. Despite its large size, a full-grown Trumpeter Swan has also fallen victim to a Snapping Turtle: Moriarty (1990) described how a Snapping Turtle drowned a yearling Trumpeter Swan weighing 14.5 kg in Minnesota.

On a 0.25 ha private pond in Aurora, Ontario (44°00'N, 79°28'W), a wild pair of Trumpeter Swans has been breeding since 2006. Each year between 2006 and 2012, one to three cygnets disappeared, probably killed by Snapping Turtles. Beginning in 2007, I watched the reaction and behaviour of full-grown Trumpeter Swans to the presence of Snapping Turtles.

The purpose of this paper is to describe aggression of Trumpeter Swans toward Snapping Turtles and injuries to Trumpeter Swan cygnets caused by Snapping Turtles.

Other injuries to Trumpeter Swans are described. The Pleistocene history and distributions of both Trumpeter Swans and Snapping Turtles are discussed.

Methods

Wild Trumpeter Swans were marked with alphanumeric wing tags at Aurora and elsewhere to distinguish individuals. Photographs were used to record injuries to cygnets and the postures and responses of Trumpeter Swans to various stimuli. A live Snapping Turtle tethered at the water's edge and a dummy Snapping Turtle moved with a cord in shallow water were used to simulate the movements of a live Snapping Turtle.

Observations

Encounters between Trumpeter Swans and Snapping Turtles: stamping behaviour

When a Trumpeter Swan sees a Snapping Turtle moving in shallow water, it moves onto the top of the Snapping Turtle's carapace and attacks by stamping. Disturbance of any kind makes a Snapping Turtle withdraw its head and legs within the overhang of the plastron and remain passive. Presumably, withdrawal is the Snapping Turtle's response to the attack. The Trumpeter Swan continues to stamp, splash, trumpet, and reach down into the water, as if pecking at the Snapping Turtle. The Trumpeter Swan may open its wings and flap, perhaps to maintain balance.

Such attacks are very noisy and may last as long as 30 seconds before the Trumpeter Swan moves aside. While on the water, the Trumpeter Swan may duet (see below) with another bird or with its mate. When the Snapping Turtle moves again, the Trumpeter Swan resumes the attack. Episodes of stamping and pausing may last for many minutes and continue until the Snapping Turtle reaches deeper water and is no longer visible.

On 11 June 2007 at 1520 EST, I was attracted by trumpeting and splashing. A yearling male Trumpeter Swan (wing tag no. 090) was attacking a Snapping Turtle. The water was shallow and the top of the Snapping Turtle's carapace was barely covered and was visible. This sequence of attack and pause lasted about 2.5 minutes.

On 13 June 2008 at 2050 EST, an eight-year-old male (wing tag no. 812) was attacking a Snapping Turtle. His mate, a seven-year-old female (wing tag no. 839) with four cygnets clustered round her sat on the water some 4 m away and did not participate in the attack. The water was shallow (<20 cm deep), and when the Snapping Turtle moved, the top of its carapace disturbed the surface. The male Trumpeter Swan duetted (see below) with his mate in the intervals between attacks, which lasted for about 7 minutes.

On 15 June 2009 at 2010 EST, one three-day-old cygnet was missing. On 22 June at 0825 EST, I saw a second, now ten-day-old cygnet from this brood, floating dead on the water. The father (wing tag no. H24) was sitting on the water about 3 m away in about 30 cm of water. He moved forward and started a brief sequence of stamping, splashing, and trumpeting. I could not see the presumed Snapping Turtle. I intended to pick up the body of the cygnet when it drifted to shore, but when I returned about 30 minutes later it had disappeared; the Snapping Turtle may have retrieved its prey.

On 12 July 2010 at 2026 EST, an unmated now four-year-old male, 090, accompanied by a yearling female (wing tag no. C04), was looking down into the water. Male 090 moved forward and started stamping, presumably on a Snapping Turtle, which I could not see.

On 14 August 2010 at 1959 EST, the male H24 and his mate 839 in turn stamped in deep water, deep enough that I could not see the presumed Snapping Turtle. I saw two bouts of attack before they left. The eight-week-old cygnets were sitting on the water several metres away.

On 4 June 2011 at 1214 EST, a three-year-old male (wing tag no. H09) was startled by something in the water. He sidled forward with neck bent and extended in the forward posture (Figure 1). His head was tilted to one side. He was apparently watching something. He then moved quickly forward and stamped twice with his feet. This was not very vigorous and there was no splashing or calling. He was followed by the female C04, who did not participate, and they swam away together.

On 17 June 2011, three swans (male 090 followed by female C04 and the three-year-old male, H09) were moving together close to the far western shore. Trumpeter Swan 090 started to stamp, presumably on a Snapping Turtle, which I could not see. During pauses, he started a duet (see below) with female C04, with notes spaced less than 1 second apart. About 0.3 seconds after C04 had responded, male H09 joined and added to the



FIGURE 1. Forward posture of a Trumpeter Swan (*Cygnus buccinator*) at Aurora, directed at a Snapping Turtle (*Chelydra serpentina*), visible at the edge of the water in the lower right-hand corner. Photo: by H. Lumsden. 5 August 2011.

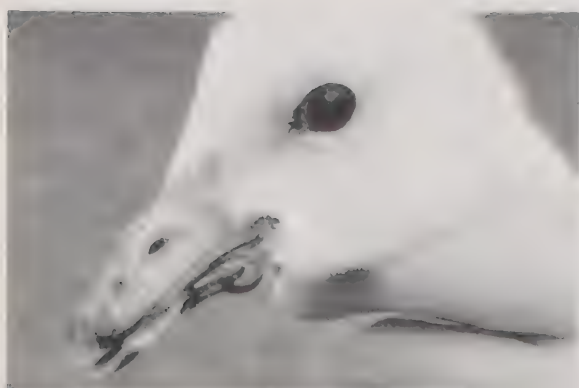


FIGURE 2A. Trumpeter Swan (*Cygnus buccinator*) cygnet from Newmarket, Ontario, showing injuries to its bill caused by a Snapping Turtle (*Chelydra serpentina*). Photo: At Aurora by H. Lumsden. 28 July 2011.



FIGURE 2B. Deformed bill of the Newmarket cygnet at six weeks of age. Photo: At Aurora by H. Lumsden. 2 September 2011.

“duet”. Thus these three companions participated in a pattern that often involves only two birds.

The Snapping Turtles which the swans attacked were later trapped. The larger weighed 9.3 kg and the smaller 3.4 kg.

Injuries to Trumpeter Swans caused by Snapping Turtles

On 10 July 2011, P. Calverley was attracted by stamping behaviour on a Snapping Turtle by a breeding male Trumpeter Swan on his pond near Newmarket, Ontario (44°03'N, 079°28'W). The attack forced the turtle to release a cygnet, which was immediately rescued by Calverley. The cygnet's injuries were severe. Part of the left side of the mandible had been bitten off and the edge of the adjacent part of the maxilla had been removed (Figure 2a). By six weeks of age, the cygnet had developed a very deformed bill (Figure 2b).

On 7 February 2011, I caught a cygnet for banding at La Salle Park, Burlington, Ontario (44°18'N 079°51'W). It had a similar injury to its bill. The terminal half of the left side of the mandible had been severed and

ripped away to its tip (Figure 3a). The remainder of the lower mandible was sharply deflected to the left. The edge of the maxilla had also been removed, and the cygnet's tongue protruded from the injured side of the bill (Figure 3b). These deformities prevented full occlusion of the bill, and this limited the cygnet's ability to feed (e.g., the cygnet was unable to pick up single grains of corn spilled on the ice). However, the cygnet was able to engulf and swallow corn from a bucket. The injury had completely healed.

The cygnet was just over 7 months old and did not appear to differ in size or the development of the body molt from its siblings. The injury probably occurred some time just before freeze-up, after the cygnet had achieved its current stature. It was not weighed but was noticeably light. The cause of deformity was not witnessed, but the strong similarity of the injury to that of the Newmarket cygnet suggests a Snapping Turtle attack.

In August 2010, E. Kaiser photographed a cygnet near Little's Corners, Ontario (43°21'N, 80°16'W), with



FIGURE 3A. Trumpeter Swan (*Cygnus buccinator*) cygnet from La Salle Park, Burlington, Ontario, showing injuries to its bill, presumably caused by a Snapping Turtle (*Chelydra serpentina*). The cygnet's age was about seven months. Photo: At La Salle Park by J. Kee. 7 February 2011.



FIGURE 3B. Frontal view of the cygnet from La Salle Park showing bill deformities that prevented full occlusion of the bill. Photo: At La Salle Park by J. Kee. 7 February 2011.

a scarred bill and forehead (Figure 4a). The cause of these injuries was not witnessed, but one can only note that they are compatible with a Snapping Turtle attack.

The wild Trumpeter Swans wintering at La Salle Park, where they concentrate and are fed, provide an opportunity to examine the bills of many of the birds present. K. Intini (personal communication) found that 4 of the 200 Trumpeter Swans present in the winter of 2010-2011 had sections of the tip of the maxilla removed in a highly stereotypical manner. One side of the maxilla was affected. Three of these birds had been banded and carried wing tags numbers 508, 029, and E97. When they were marked as cygnets, there was no record of bill injury.

An unmarked Trumpeter Swan wintering on Lake Ontario at Bluffer's Park in Toronto, Ontario (43°42'N, 79°14'W) in 2009 was similarly affected. A five-year-old male (wing tag no. C24) photographed on 9 June 2011 by D. Bell at Colonel Sam Smith Park on Lake Ontario in Etobicoke (43°25'N, 79°32'W) had a section removed from the right side of his bill (Figure 4b). A captive breeding female (wing tag no. 122), held on an artificial pond at King City, Ontario (43°56'N, 79°32'W), was attacked, presumably by a Snapping Turtle, and lost nearly 1 cm from the end of the maxilla. She survived the attack.

The fact that Snapping Turtles sometimes prey on adult Trumpeter Swans is confirmed by Moriarty (1990). The bill damage is consistent with what one would expect from the bite of a Snapping Turtle. There were no witnesses to the events that led to most of the injuries described above. One cannot eliminate other causes, such as encounters with traps set for Muskrats (*Ondatra zibethicus*) or outboard motor propellers. Caution must be used when using indirect evidence as inference of predation on waterbirds by Snapping Turtles (Igl and Peterson 2010).

Behaviour of Trumpeter Swans

Duetting

The triumph ceremony of the Whooper Swan (*Cygnus cygnus*) was described as a duet (Ferguson-Lees et al. 1977). Johnsgard (1968) also described duetting displays of other species of the tribe Anserini. Trumpeter Swans perform a duet of a different and distinctive kind in response to potential predators. A duetting pair stands in the upright posture (see below) with the neck sleeked. The male utters a short, sharp trumpet-like note, which is immediately answered by the female, usually less than 1 second later, at a slightly higher pitch. These duets are usually repeated at 3–4 second intervals. They may be performed by mated pairs or by two companion Trumpeter Swans when disturbed by a variety of predators. Duets are sometimes performed during pauses between stamping attacks on a Snapping Turtle.

When Trumpeter Swan cygnets are caught for banding in fall and winter at La Salle Park and elsewhere



FIGURE 4A. Trumpeter Swan (*Cygnus buccinator*) cygnet at Little's Corners, Ontario, showing injuries to its bill and forehead that may have been caused by a Snapping Turtle (*Chelydra serpentina*). Photo: by E. Kaiser. August 2011.



FIGURE 4B. Adult Trumpeter Swan (wing tag no. C24) at Col. Sam Smith Park, Etobicoke showing a notch missing from the bill that may have been caused by a Snapping Turtle. Photo: D. Bell. 5 June 2011.

(Lumsden, personal observations), the male parent, the primary defender of the brood, typically backed by the female, advances aggressively and stands 5 to 10 m from the bander, displaying in the upward posture (Figure 5), and starts the duet. The parents continue to call until the cygnet is released.

Two cygnets from an isolated brood at Leaskdale, Ontario (44°12'N, 79°10'W), were caught in a drop-door trap placed on top of a bank. The parents were in the water below the bank and could not see the cygnets

or the banding process. They duetted repeatedly, with the notes spaced about 3 seconds apart. When a cygnet was caught for banding at Claremont, Ontario (43°58'N, 79°07'W), on 13 February 2012, the parents duetted as usual. Immediately 14 other Trumpeter Swans that had gathered there for food clamoured (see below) using the same duetting calls. When a male (wing tag no. 140) and his mate were frightened by a domestic dog at La Salle Park, they adopted the upward posture (Figure 5) and duetted. The Trumpeter Swan pair H24 and 839 at Aurora responded to a dog in a similar manner.

On 2 February 2012 at Bluffer's Park in Toronto, the Trumpeter Swan pair (wind tag no. J42 and wing tag no. A70) duetted as I approached. I have never seen Trumpeter Swans in Ontario respond in this way to the approach of a human. In this case, this pair probably recognized me as a predator because I had caught and tagged both of them and between 2004 and 2010 I had caught and banded their cygnets. Their duetting attracted the other 18 Trumpeter Swans in Bluffer's Park. They gathered nearby, and their collective duetting calls amounted to clamouring.

Clamouring

A pair of Trumpeter Swans duetting in the presence of a predator stimulates other Trumpeter Swans that may be nearby to concentrate and clamour. They join the duetting pair with a chorus of "duet calls". With many Trumpeter Swans present, the noise can be very loud and sustained. This clamouring is a form of mobbing (McFarland 1987), which informs the entire wetland community that a predator is present.

Forward posture

On 5 August 2011, I tethered a live Snapping Turtle near the shore of the pond at Aurora. This released the forward posture in male H24 (Figure 1). The bird stood motionless, silent, on the alert with the neck sleeked and extended forward and with bill pointing at the Snapping Turtle. He watched intently for more than half a minute. On 24 May 2011, a dummy Snapping Turtle moved by pulling a cord released the forward posture in male H24, 18 days before his cygnets hatched.

Upward posture

The Trumpeter Swan stands motionless and alert, with the neck sleeked and extended upward, the forepart of the body slightly raised (Figure 5). This posture is usually adopted when duetting in response to predators.

Similarity between the stamping behaviour and the water treading display

The stamping behaviour may have evolved from a very similar Trumpeter Swan behaviour that de Vos (1964) described as the water treading display. This threat display is usually directed at an intruder at the boundary of a territory. For example, in the Aurora study area, injured Trumpeter Swans were occasionally confined in a small pen at the corner of the main



FIGURE 5. Upward posture of Trumpeter Swans (*Cygnus buccinator*) at La Salle Park, adopted when duetting or when startled by a domestic dog. Photo: H. Lumsden. 22 March 2011.

pond. The resident breeding male frequently performed the water treading display at the boundary fence adjacent to the "intruding" injured bird.

During the water treading display, the aggressor does not trumpet while it stamps vigorously and with loud splashing, raising the forepart of its body, shaking its wings, and extending its neck forward (Figure 6) (photo by de Vos by permission). There is broad similarity between the water treading display and the stamping behaviour.



FIGURE 6. Water treading display by a male Trumpeter Swan (*Cygnus buccinator*). Photo: A. de Vos. Reproduced from de Vos. 1964. Observations on the behaviour of captive Trumpeter Swans during the breeding season. *Ardea* 52: 166–148. Used with permission.

Discussion

The stamping behaviour on Snapping Turtles described above was performed by both yearling and adult and by both female and male Trumpeter Swans. The stamping behaviour appears to be a fixed action pattern (Lorenz 1970), which is an instinctive rather than a learned behaviour. This behaviour appears to be released by a Snapping Turtle swimming below the surface of the water. I tried to release the stamping behaviour using a dummy Snapping Turtle moved by pulling a cord. I subsequently used a live Snapping Turtle tethered near the shore, but it would not swim. Both failed to release the stamping behaviour.

The stamping attack at Newmarket by the parent forced the Snapping Turtle to release the cygnet it had seized, thereby saving its life. Similarly, stamping attacks may have been involved in the survival of other cygnets showing evidence of possible turtle attack (e.g., Figures 3a and b, and 4a and b).

Although Snapping Turtles are omnivores and opportunistic foragers, they are also ambush predators (Earnst et al. 1994). They likely choose an ambush site which provides the best opportunities for seizing prey. The stamping behaviour may disrupt a predation opportunity, cause the Snapping Turtle to abandon an optimal site, and move to one that is less favourable.

Lamprecht et al. (1985) described duetting in semi-captive Bar-headed Geese (*Anser indicus*) at Seewiesen in Germany. He characterized the duetting call as the distance call. The young of a pair of Bar-headed Geese were abducted, and the duetting was led by the female (the incubator and primary brood care giver) on return while looking for her goslings at the site from which they had been removed. Lamprecht et al. (1985) suggested that the response of the male relieved the female from visually monitoring her mate's whereabouts.

Hall (2004) discussed 10 hypotheses that addressed the function of duetting in birds. In only one of the 10 hypotheses she suggested that duetting may function as a means to protect birds and their young from predation or to confuse predators during a predation attempt. Duetting does not appear to protect Trumpeter Swans from Snapping Turtle attacks nor to confuse Snapping Turtles. However, duetting and clamouring appear to be a form of mobbing (McFarland 1987), which might be added to the 10 hypotheses of Hall (2004).

Pleistocene distribution

The range of the Snapping Turtle extends from southern Canada west to the foothills of the Rocky Mountains and east to the Atlantic coast and as far south as Florida and northeastern Mexico (Conant 1975) (Figure 7).

Prior to European settlement, the range of Trumpeter Swan was very extensive (Mitchell and Eicholz 2010). It extended from southern and central Alaska south and east through central Canada and the north-



FIGURE 7. Map of North America showing the distribution of Trumpeter Swans (*Cygnus buccinator*) (green) (Mattson et al. 1985), Snapping Turtles (*Chelydra serpentina*) (red), (Conant 1975) and where the two species' ranges overlap (yellow) during the Pleistocene. The red asterisk denotes the location of a Snapping Turtle fossil uncovered in Glendale, Nevada. The southern limits of the Wisconsin glaciation are shown by the solid blue line (1), and the limits of the Yellowstone glacier are shown by the solid black line (2). The 300-foot marine contour (3) indicates the strandline (shoreline) during the Pleistocene.

ern half of the United States (Mattson et al. 1985). It bred from the Atlantic coast (Lumsden 2013) to the Pacific.

Historically, the range boundaries of these two species did not remain static. There were 18 to 20 glacial cycles during the 2.6 million years of the Pleistocene (Graham 2011). Each of the four major glacial advances of Pleistocene ice had a fundamental impact on the distribution of both species. They would have been confined to areas well south of the Great Lakes in the east and south of the 49th parallel in the west. The southern limit of the Wisconsin glaciation is shown in Figure 7. Thus, at the peak of glaciation, all of the breeding range of the Trumpeter Swan east of the Rocky Mountains would have been confined within the range of the Snapping Turtle.

The glacial ice sheets changed sea levels, temperatures, and precipitation patterns, which in turn influenced the distribution of the Snapping Turtle and the Trumpeter Swan. In the Gulf of Mexico, the Pleistocene shoreline, now submerged, indicates a substantial marine retreat. The strandline has been located about 300 feet below current sea levels (Muhs et al.

2004) (Figure 7). As the glaciers advanced, marine, freshwater, and terrestrial habitats would have expanded or changed. The new habitat and cooler conditions would have permitted Trumpeter Swans to expand their breeding range southward.

The range of the Snapping Turtle also expanded, probably southward and westward into the Mohave Desert during these glacial cycles. Fossil Snapping Turtle bones were excavated near Glendale, Nevada (36°39'N, 114°34'W) (indicated by asterisk in Figure 7), well outside the current range of the Snapping Turtle. The fossils date from about 35 000 Years Before Present, just before the peak of the Wisconsin glaciation (Van Devender and Tessman 1975). Increased precipitation and changes in wetland conditions likely provided habitat for the Snapping Turtle and perhaps Trumpeter Swans in what is now the Mohave Desert.

There are no Snapping Turtles within the present breeding range of the Rocky Mountain population of the Trumpeter Swan (R. Shea, personal communication). Trumpeter Swans from this Rocky Mountain population were used in the restoration program in Ontario (Lumsden 2002), and they exhibit the stamping behaviour. This suggests that this population must have been exposed to Snapping Turtle predation at some time in the past.

At the peak of the Wisconsin glaciation, much of the breeding range of the Rocky Mountain population of the Trumpeter Swan was covered by the Yellowstone glacier (Pierce 2003) (Figure 7). Both the Wisconsin glaciation and the Yellowstone glacier would have been bordered by a zone of tundra that was underlain by permafrost 80–200 km wide (Graham 2011) which graded into an open spruce forest. The duration of the ice-free period in this permafrost zone would have been too short for Trumpeter Swans to complete their nesting cycle, according to Hansen et al. (1971), Trumpeter Swans breeding in Alaska need 140–154 ice-free days to complete their nesting cycle). During the Pleistocene, Trumpeter Swans would have been widely displaced to the south beyond the tundra zone, and individuals from lower elevations would have recolonized the area as the ice retreated. These colonists would have been birds that had evolved under the selective pressure of Snapping Turtle predation.

To my knowledge, the Pacific coast population of the Trumpeter Swan, which breeds west of the Rocky Mountains and in Alaska, has never encountered Snapping Turtles during the nesting season. Evolutionarily, this population was under no selective pressure to develop behaviours that deter Snapping Turtle predation. Many of the Trumpeter Swans that were used to restore populations in the U.S. Midwest came from Alaskan stock. The speed with which this genetically distinct (Oyler-McCance et al. 2007) stock, whether or not it possessed an anti-turtle defence, established itself in the mid-western United States suggests that Snapping Turtle predation was not an important factor.

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Tree Ring Growth and Stable Isotopes as Potential Indicators of Historical Seabird Activities on Forested Islands in Coastal British Columbia

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We examined yearly rings from increment cores of conifers on two seabird nesting islands (one in the Lucy Islands and one in the Rankine Islands, British Columbia), to determine whether trees contained signatures of historical activity of seabirds. Ten conifers (primarily Sitka Spruce, *Picea sitchensis*), ranging from 56 cm to 127 cm diameter (average 90 cm) and ranging from 70 to 232 years in age (average 132 years of age), were cored across a 200-m gradient in densities of seabird burrows. At the site in the Lucy Islands, annual growth was highest (8–14 mm) in the trees with the highest seabird burrow densities and highest in the earliest rings (~1930), which were followed by a fluctuating reduction down to ~2 mm year in the year 2000, but with a secondary elevated growth period in the 1970s. Adjacent control trees without seabird burrows had a growth rate of ~2 mm/year throughout the same period. At the site in the Rankine Islands, growth rates were also variable and exhibited a 10–15 year non-synchronous periodicity, with the highest growths in the location with high seabird burrow density. Nitrogen isotope signatures ($\delta^{15}\text{N}$), which are greatly elevated in seabird guano, ranged from minus 3.9‰ to 17.4‰ among tree rings ($n = 245$ rings) and were positively correlated to percentage nitrogen in rings, average ring growth, and burrow densities. Using these methods, we infer from our tree ring data that seabird activity declined on the Lucy Islands over a 70-year period and that the combination of growth, nitrogen isotopic signatures, and percentage nitrogen in tree rings as well as a more detailed sampling grid of target and adjacent control trees will provide seabird biologists with additional tools for evaluating spatial and historical trends in seabird activity on forested islands.

Key Words: Alcidae; *Picea sitchensis*; Sitka Spruce; Rhinoceros Auklet; *Cerorhinca monocerata*; Cassin's Auklet; *Ptychoramphus aleuticus*; burrows; colony; historical activity; percentage nitrogen; stable isotopes; tree rings; British Columbia

Seabirds have a significant impact on terrestrial plant communities (reviewed in Ellis 2005). Elevated nitrogen levels as well as ^{15}N enrichment are reported in soils and grasses from seabird colonies in California, as guano is greatly enriched in ^{15}N (Mitzutani and Wada 1988; Anderson and Polis 1998; Wait et al. 2005). Values of $\delta^{15}\text{N}$ (ratio of $^{15}\text{N}/^{14}\text{N}$ in sample relative to air reference) from soil cores have been used to determine the length of time seabirds have occupied an area and to identify when a site was abandoned (Mitzutani et al. 1991; Hawke 2004). However, microsite differences in the extent of nutrient leaching and differences in the extent of microbial processing of nitrogen, as well as in the volatilization of nitrogen, appear to limit the general application of nitrogen isotopes as historical indicators of seabird activity (reviewed in Hart and Classen 2003).

Growth rates and stable isotope analysis of tree rings have been used to identify spatial and temporal trends in nitrogen cycling in forests (Bukata and Kyser 2007; Holdaway et al. 2007; Mizota 2009; Mizota et al. 2011). Large transfer of Chum Salmon (*Oncorhynchus keta*) biomass from streams to riparian zones by American Black Bears (*Ursus americanus*) in coastal British Columbia (Reimchen 2000) is associated with an uptake of these nutrients by riparian vegetation, as evidenced by the enrichment of $\delta^{15}\text{N}$ in foliar tissues (Reimchen 2001; Mathewson et al. 2003; Wilkinson et al. 2005)

and in tree rings (Reimchen et al. 2003). There is evidence of a correlation between $\delta^{15}\text{N}$ signatures in tree rings and recent numerical counts of Chum Salmon (Drake and Naiman 2007). Experimental application of a ^{15}N tracer to simulate decomposition of Chum Salmon showed that Western Red Cedar (*Thuja plicata*) immediately utilized the tracer (Drake et al. 2006). Yet, variability in $\delta^{15}\text{N}$ enrichment can have multiple and diverse causes, including changes in precipitation and temperature (Handley et al. 1999), changes in the soil microbial use of the nitrogen pool (Robinson 2001), and translocation of nitrogen in the sapwood (Drake et al. 2006; Balster et al. 2009), all of which confound any simple proxy between $\delta^{15}\text{N}$ enrichment and temporal trends in nitrogen sources (Koopmans et al. 1997).

Alcids and storm-petrels (*Oceanodroma* spp.) nest in burrows on numerous small forested islands off the coast of British Columbia. The daily deposition of guano would increase over the nesting period, particularly for species such as Rhinoceros Auklet (*Cerorhinca monocerata*) and Cassin's Auklet (*Ptychoramphus aleuticus*), whose young are fed over an extended pre-fledging phase (Campbell et al. 1990). Forests around the rim of the northern Pacific Ocean are generally nitrogen-limited (Schulze et al. 1994), and we expected to observe substantial spatial heterogeneity in nitrogen uptake associated with the input of guano.

During a coast-wide field survey of riparian vegetation on salmon rivers in British Columbia in September 2000 (Reimchen et al. 2003), we visited two small forested islands (one in the Lucy Islands and one in the Rankine Islands, Figure 1). Each island has a small nesting colony of alcids during spring (Rodway 1991; Reimchen, personal observation). We cored 12 conifers across a gradient in burrow densities to assess the potential application of tree rings in estimating relative seabird activity. In this paper, we describe radial growth patterns (years ~1925 to 2000), $\delta^{15}\text{N}$ signatures, and percentage nitrogen for a subset of years. We predicted that we would find elevated tree growth, enriched $\delta^{15}\text{N}$, and elevated percentage nitrogen from trees near high burrow densities relative to control trees in adjacent regions (50–100 m) without burrows.

Methods

The Lucy Islands site ($54^{\circ}17'\text{N}$, $130^{\circ}37'\text{W}$) is 15 km west of Prince Rupert, northern British Columbia. It has a colony of approximately 25 000 Rhinoceros Auklets, with most burrows within 100 m of the shoreline (Rodway 1991; Gaston and Dechesne 1996). The Rankine Islands site ($52^{\circ}19'\text{N}$, $131^{\circ}16'\text{W}$) is 225 km southwest of Prince Rupert off the southeastern coast of Moresby Island in the Haida Gwaii archipelago. It has a mixed colony of Cassin's Auklet, Ancient Murrelet (*Synthliboramphus antiquus*), and Leach's Storm-Petrel (*Oceanodroma leucorhoa*). All species total ~20 000, with most burrows occurring on the southeastern edge of the island (Lemon, personal communication).

On the two islands, we identified 15 of the largest trees (14 Sitka Spruce and 1 Western Hemlock, *Tsuga heterophylla*) and 2 Sitka Spruce saplings as size controls, each of which was cored. Twelve of the 17 trees yielded sufficiently intact cores for ring measurements. Circumference at breast height (~1.3 m) (converted to diameter at breast height (dbh)) and distance to the shoreline (m) were measured for each tree. General habitat characteristics such as slope and indicators of seabird nesting activity (burrows, guano, and feathers) were recorded. As these observations were made on September 12 and September 22 for Lucy and Rankine Islands, respectively, after the nesting season, we could not reliably differentiate active from inactive burrows.

There was no clear evidence for alternate nitrogen sources such as Bald Eagle (*Haliaeetus leucocephalus*) activity and North American River Otter (*Lontra canadensis*) latrines that could substantially influence nitrogen sources near the cored trees, although wind-driven marine flotsam such as macrophytes could accentuate the input of nutrients to those trees near the shoreline. We suspect the influence is very limited, given that more permanent flotsam such as wood debris and plastic flotsam was common immediately above the high tide marks yet was absent higher in the areas where coring was done.

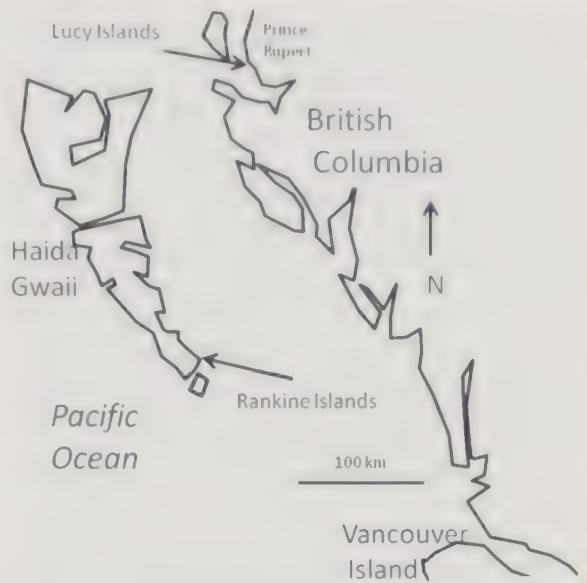


FIGURE 1. General location of Lucy and Rankine Islands in coastal British Columbia.

On each island, we chose trees to be cored along a transect perpendicular to the high tide mark across a sharp gradient in burrow densities. These included trees near the most central part of the islands, without burrows, through to trees closer to shore, where burrow entrances (<2 m from the tree base) were most abundant (>10 burrows per tree base). We assume that number of entrances generally correlates with number of burrows. As well, as much as possible, we also chose trees of similar size to reduce differences in root areas and depths, as nitrogen isotope signatures increase with soil depth (Koopmans et al. 1997).

At the Lucy Islands site (Lc), each of the 6 trees cored was situated within a flat zone on the southeastern region of the island. At ~150 m from the waterline and ~20 m elevation, 2 trees 50 m apart in an area without burrows were cored (identified as Lc2n and Lc3n) (Lc2n dbh = 0.56 m, age ~147 years; Lc3n dbh = 0.65 m, age ~109 years). At the intermediate location, 100 m from the waterline, burrows were present but uncommon ($b = 1\text{--}2$ burrows/tree base). Two trees in this area were cored at 100 m from the waterline, identified as Lc6b and Lc7b (Lc6b dbh = 0.56 m, estimated age ~81 years; Lc7b dbh = 0.92 m, age ~70 years). At the inner location, 50 m from the waterline and ~10 m in elevation, burrow densities were high ($bb = >10$ burrows per tree base). Here 2 further trees were cored, identified as Lc5bb and Lc1bb (Lc5bb dbh = 0.92 m, age ~107 years; Lc1bb dbh = 1.18 m, age ~159 yrs). Each tree chosen for coring was the largest Sitka Spruce in the area and was approximately 50 m from the nearest cored tree.

At the Rankine Islands site, 6 trees (5 Sitka Spruce and 1 Western Hemlock) from the southeastern region of the large island, all within a zone 200 m wide along

the slope, were cored. The control site, identified as Rk4n, was near the top of the island, where burrows were least common (Rk4n dbh = 0.91 m, age ~126 yrs). The location identified as Rk3b was 100 m to the southeast of Rk4n on a 45° slope with numerous burrows (Rk3b dbh = 1.27 m, age ~232 years). The location identified as Rk8bb (Rk8bb dbh = 0.92 m, age ~70 years) was on the eastern edge of the island, which is the major site for burrows. Also, at this location, which had a high number of burrows, we cored a Western Hemlock, identified as Rk7WHbb. This tree had previously been metal tagged (CAAU Plot 3, Bearing Point D270) and is part of a British Columbia seabird inventory monitoring program begun in 1984 (Lemon, personal communication) (Rk7WHbb dbh = 1.08 m, age ~225 years). Each of the cored trees was the largest within the area.

To examine potentially confounding associations between tree size and isotopic signatures, we also cored two Sitka Spruce saplings, identified as Rk4sn and Rk8sbb. Sapling Rk4sn was 3 m from the base of Rk4n. There were no burrows in this area (Rk4sn dbh = 0.048 m, age = 16 years). The second sapling was 2 m from Rk8bb. Burrows were abundant in this area (Rk8sbb dbh = 0.11 m, age = 11 years).

Cores were extracted with an increment borer (length = 40 cm, diameter = 1.2 cm; Haglölöf Inc, Sweden) and placed in solid plastic tubes with netted ends. These were returned to the boat and stored vertically over a drying fan until they could be returned to the lab (~three weeks), where they were placed in a drying oven at 60°C for at least two to three weeks until dry and then stored at room temperature. Each core was sanded with progressively finer sandpaper until smooth and then digitally scanned at 1200 dpi.

For analyses of yearly growth, the total ring width was measured to the nearest 0.01 mm using WinDENDRO (Version 6.1D, 1998, Regent Instruments Inc., Sainte-Foy, Quebec) with visual checks for each software-defined ring position (Guay et al. 1992). The actual year assigned to specific rings is accurate on the outer reaches of most cores but becomes less reliable as one progresses towards the base of the core, due to ambiguous or missing rings. Using the dendrochronology program COFECHA (Holmes, 1983) we examined cross-correlations against a master dating chronology (Grissino-Mayer 2001) for each island and made marginal adjustments for missing or false rings in 4 of the 12 cores. Average correlations with the master chronology were relatively low (Lucy Islands site 0.29, range among trees 0.0–0.42; Rankine Islands site –0.24, range among trees 0.06–0.77).

For nitrogen analyses, selected rings were recovered with a scalpel blade under a dissecting microscope. In both field and laboratory protocols, we avoided direct human skin contact to minimize contamination of the cores. Detailed methodology on isotope analyses is given in Reimchen et al. (2003). Each wood sample

(N=245) was individually ground to a fine powder on a Wig-L-Bug grinder (Crescent Dental Co., Chicago, 111). Thirty mg (accurate to within 0.05 mg) of each ring was packaged in a 5 × 12 mm tin capsule.

Signatures of $\delta^{15}\text{N}$ and percentage nitrogen from powdered wood were determined after online combustion of samples in an elemental analyzer (ANCA-Hydra 20–20, PDZ Europa, Stable Isotope Facility, University of California-Davis, California). Combustion of the samples was achieved at 1050°C with a 40 mL oxygen injection and a Cr_2O_3 catalyst. Reproducibility of isotopic values on replicated samples averaged $\pm 1.0\text{‰}$.

Several recent publications suggest that removal of mobile nitrogen from the sapwood provides a more reliable isotopic proxy of the bound nitrogen in recent tree rings than total nitrogen (Hart and Classen 2003; Elhani et al. 2003). We analyzed both sapwood and heartwood but we excluded data from sapwood from the majority of our analyses and discuss primarily data from the heartwood rings. This provides a more reliable measure of any long-term trends in the uptake of nitrogen from the soil (Hietz et al. 2010). As well, we exclude analyses of percentage nitrogen during the last decade of growth, as nitrogen levels increase sharply at the start of the sapwood (Balster et al. 2009), usually near the early 1980s in our cores.

We obtained yearly precipitation and temperature data from Environment Canada for a weather station on the Lucy Islands (1920–2000) and at Sandspit and Masset, Haida Gwaii (1940–2000), the latter representing the closest stations to the Rankine Islands. We also compared growth against Pacific climate oscillation (Mantua et al. 1997).

Results

Tree growth

At the Lucy Islands site, yearly growth rate of trees ranged from 0.1 mm/year to 15 mm/year (Figure 2). The two trees from locations with low burrow densities (Lc2n, Lc3n) had relatively little growth (~2 mm/year) from 1925 to 2000. In contrast, trees from locations with high burrow densities, Lc1bb and Lc5bb (which were 100 m from Lc2n and Lc3n), each had high growth rates during the 1930s (8–14 mm/year). This fell non-linearly to 2 mm/year in recent years. Lc5bb showed additional elevated growth (~6 mm/year) in the 1970s. This growth was not evident in Lc1bb.

The two trees from the location with intermediate burrow density (Lc6b, Lc7b) also showed moderately elevated growth in the early 1930s (~6 mm/year). This fell rapidly in the late 1930s, concurrent with a similar reduction in the growth rate in Lc1bb and Lc5bb. Yearly growth of Lc6b remained low (~2 mm/year) throughout the time period, while Lc7b showed significant increased growth in the 1970s before falling to 2000.

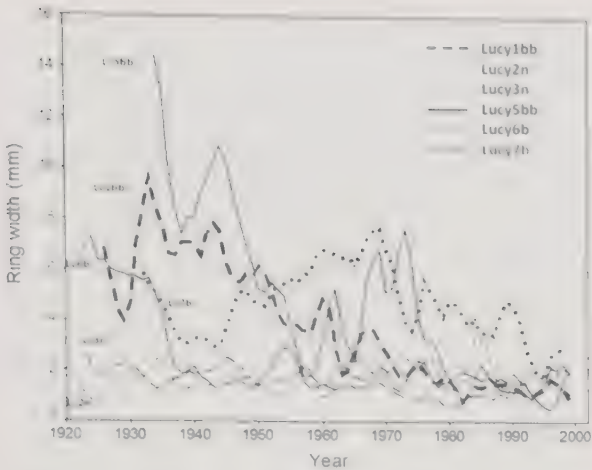


FIGURE 2. Yearly tree ring growth (mm) for Sitka Spruce (*Picea sitchensis*) at the seabird colony on the Lucy Islands, British Columbia, 1920–2000, from cores made in September 2000. Lines represent three-point moving average of yearly growth for six trees. Tree code (Lc#) shows relative seabird burrow abundance at base of tree: no burrows—n; 1–2 burrows—b; >10 burrows—bb.

At the Rankine Islands site, there were substantial fluctuations in tree growth over time, with an irregular periodicity of 10 to 15 years (Figure 3). The peak growth in the mid-1970s was generally synchronous among the four large trees ($r > 0.48$ for each comparison), but there was no overall consistency among the four trees for the period 1925–2000 ($P > 0.05$). The highest growth rate (range 5–11 mm/year) occurred in Rk8bb, which was at the location with the highest seabird burrow densities. The single Western Hemlock

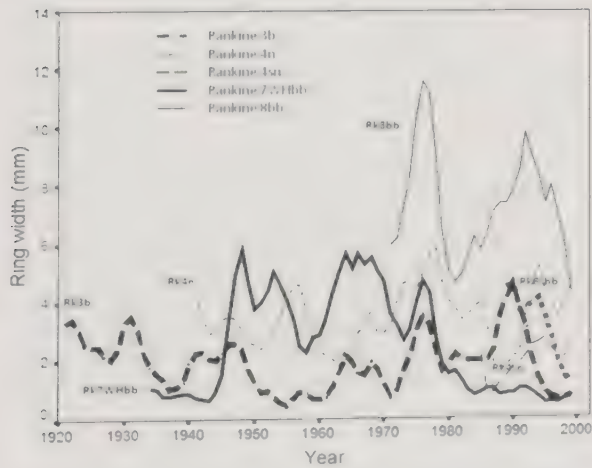


FIGURE 3. Yearly tree ring growth (mm) for conifers at the seabird colony on the Rankine Islands, British Columbia, 1920–2000, from cores made in September 2000. Lines represent three-point moving average of yearly growth. Tree code (Rk#) shows relative seabird burrow abundance at base of tree: no burrows—n; 1–2 burrows—b; >10 burrows—bb. All trees are Sitka Spruce (*Picea sitchensis*) except Rk7whbb, which is Western Hemlock, *Tsuga heterophylla*.

(Rk7whbb), adjacent to Rk8bb, had low growth rates (~1 mm/year) in the 1940s but this increased sharply thereafter and varied between 2 mm/year and 6 mm/year before falling to ~1 mm/year from 1980 to 2000.

The two saplings used as size controls from locations with low and high burrow densities (Rk4sn and Rk8sbb, respectively) each had approximately one-half the annual growth rate of their respective larger counterparts. They exhibited a strong correlation in yearly trends with their larger counterparts ($r > 0.75$, $P < 0.01$) but not with each other ($r = -0.3$, $P = 0.35$).

Nitrogen isotopes

Isotopic signatures among trees varied spatially at the two sites. Average $\delta^{15}\text{N}$ enrichment (excluding sapwood) ranged from 1‰ to 10‰ among the 12 trees and was higher on the Lucy Islands site than on the Rankine Islands site ($\delta^{15}\text{N} = 6.5$ and 4.5, respectively; $F_1 = 27.1$, $P < 0.001$) (Figure 4). Range among individual rings was large on both islands (Lucy Islands site -1.7‰ to 17.4‰; Rankine Islands site -3.9‰ to 10.9‰).

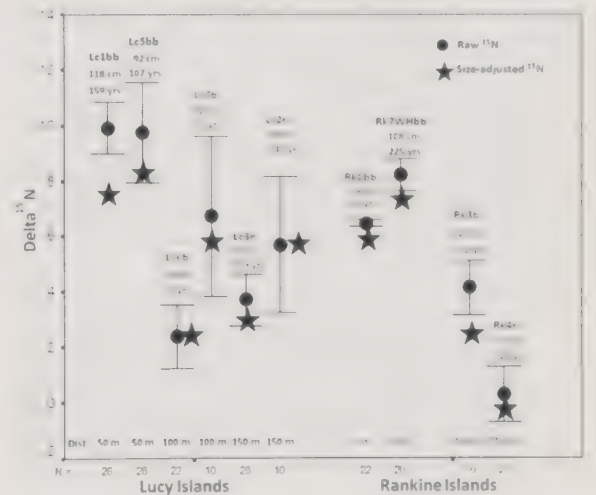


FIGURE 4. Mean $\delta^{15}\text{N}$ signatures in yearly growth rings from conifers at two seabird colonies (one in the Lucy Islands and one in the Rankine Islands) in northern British Columbia in September 2000. For each island, trees are arranged from locations with abundant burrows to sites with no burrows. N = number of individual rings analyzed per tree. Dist = tree distance (m) from the high tide mark. DBH = diameter (m) at breast height; Age = actual or estimated age of tree; Star = isotopic signatures standardized to the smallest tree dbh in each colony. Tree code shows relative seabird burrow abundance at base of tree: no burrows—n; 1–2 burrows—b; >10 burrows—bb.

Isotopic enrichment was highest in sites where burrow density was the highest and lowest 100 m further inland, where burrows were uncommon (Lucy Islands site $F_{1,4} = 5.0$, $P = 0.09$; Rankine Islands site $F_{1,4} = 28.7$, $P = 0.006$). Although the number of trees sampled is too low to allow useful statistical interpretations to be

made, the spatial trends in $\delta^{15}\text{N}$ at the Lucy Islands site co-varied with tree size, as the largest and smallest trees showed the highest and lowest isotopic signatures, respectively (Figure 4). The spatial trends at the Rankine Islands site did not co-vary with tree size.

There was extensive temporal variation in isotopic signatures. The majority of trees exhibited increased $\delta^{15}\text{N}$ enrichment from 1920 to 2000 (Figures 5 and 6). Nine of the ten regression slopes were significantly different from zero ($P < 0.001$ in all cases), and in each island there were statistical differences among slopes (Lucy Islands site ANCOVA interaction term $\delta^{15}\text{N} \cdot \text{Year}$ $F_5 = 9.6$, $P < 0.01$; Rankine Islands site $F_3 = 38.4$, $P < 0.01$).

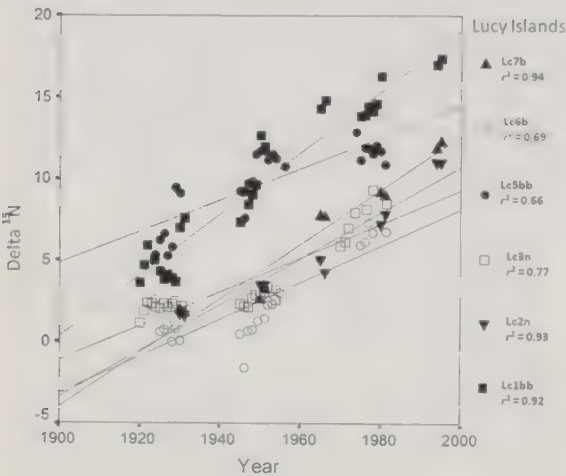


FIGURE 5. Temporal trends in $\delta^{15}\text{N}$ signatures in yearly tree rings for the seabird colony on the Lucy Islands in coastal British Columbia, 1920–2000, from cores made in September 2000. Best-fit linear regression shown for each core. Tree code shows relative seabird burrow abundance at base of tree: no burrows—n; 1–2 burrows—b; >10 burrows—bb.

There were no consistent differences in slopes between the locations with high burrow densities and the locations with no burrows, although the intercept was higher in the former. The average enrichment over this 70-year period was $\sim 10\text{‰}$ for the Lucy Islands site and $\sim 5\text{‰}$ for the Rankine Islands site. Exclusion of sapwood years (>1980) did not seriously alter this trend, as 8 of 10 regression slopes remained highly significant ($P < 0.01$).

The increased isotopic enrichment over time in most trees also co-varied with yearly increases in tree size. We tried to evaluate directly the effects of size by comparing yearly isotopic signatures in a large tree and a sapling from the same microsite (within 3 m). This showed enrichment in the larger trees both at locations with high burrow densities and at locations with low burrow densities (Figure 7). In the location with high burrow densities, enrichment of the large tree (Rk8bb) was on an average 4.9‰ higher than in the adjacent

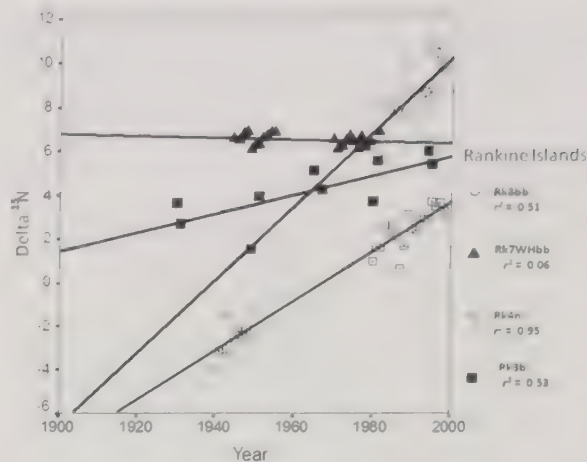


FIGURE 6. Temporal trends in $\delta^{15}\text{N}$ signatures in yearly tree rings for the seabird colony on the Rankine Islands, coastal British Columbia, 1920–2000, from cores made in September 2000. Best-fit linear regression shown for each core. Tree code shows relative seabird burrow abundance at base of tree: no burrows—n; 1–2 burrows—b; >10 burrows—bb.

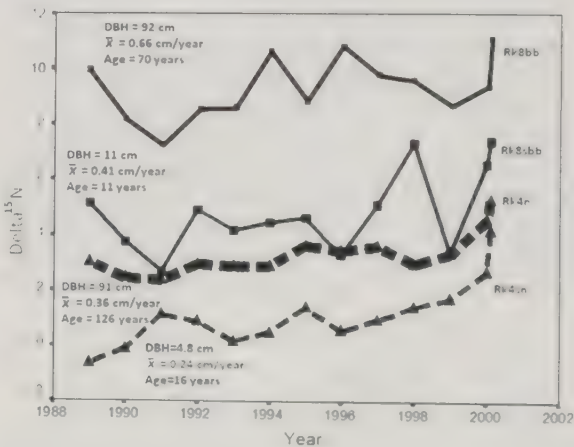


FIGURE 7. Yearly comparison of $\delta^{15}\text{N}$ signatures in paired large and small trees from locations with high burrow densities and no burrows on the Rankine Islands, British Columbia, 1988–2000. Graph shows data from two large Sitka Spruce (*Picea sitchensis*) (Rk4n and Rk8bb), each with a companion Sitka Spruce sapling as a size control. Rk4sn was located 3 m from the base of Rk4n. Rk8sbb was located 2 m from the base of Rk8bb; DBH = diameter at breast height; \bar{x} = average yearly ring growth.

sapling (Rk8sbb) among the overlapping years (paired $t = 13.5$, $P < 0.001$). At the location with low burrow densities, enrichment in the large tree (Rk4n) was on average 2.5‰ higher than in the adjacent sapling (Rk4sn) among the overlapping years (paired $t = 11.5$, $P < 0.001$).

The close physical proximity of each large tree and sapling in a pair allowed us to compare the temporal

trends in isotopic signatures over the decade. These were strongly correlated in the pair from the location with high burrow densities ($r = 0.84$, $P < 0.001$) but were only marginally but not significantly correlated for the location with low burrow densities ($r = 0.54$, $P < 0.06$). If we assume that these paired comparisons characterize the broader relationship between tree size and relative isotopic signatures, the average $\delta^{15}\text{N}$ isotopic enrichment would be 0.045‰ per cm of increased tree diameter (range $0.029\text{--}0.60\text{‰}$). Consequently, isotopic signatures were size-standardized (assuming an increment of $0.045\text{‰}/\text{cm}$) to the smallest tree (dbh = 56 cm).

This correction reduces the extent of enrichment among the larger trees but does not remove the general trends in the spatial data, which showed elevated signatures in the trees from [the areas with high burrow densities in both the Lucy Islands site and the Rankine Islands site (Figure 4). Similarly, the temporal trends from the 1930s to the recent past are slightly moderated by removing tree size effects. However, for all trees (apart from Rk7whbb), slopes remain positive, indicating general enrichment in signatures over the last seven to eight decades.

We assessed whether yearly differences in ring $\delta^{15}\text{N}$ were associated with yearly difference in the growth of each tree. For each locality, we computed the common regression slope between $\delta^{15}\text{N}$ enrichment and year for all cores combined and extracted the standardized $\delta^{15}\text{N}$ residuals for each core. Comparable residuals for each core were extracted for yearly growth based on the common regression line between ring and year. Bivariate plots of these residuals (Figure 8) yielded a significant positive correlation ($P < 0.05$) in both colonies, showing that elevated growth tends to occur with increased isotopic enrichment.

On the assumption that some proportion of the levels of $\delta^{15}\text{N}$ in each tree ring is a product of yearly differences in guano input, we predicted that increased $\delta^{15}\text{N}$ levels would be correlated with increased total nitrogen in the rings. This was confirmed, as there was a positive correlation in 11 of the 12 trees ($r > 0.4$) between these variables (9 of 11 with $P < 0.05$). The correlations may be inflated because of the sharp increase in nitrogen levels in the sapwood rings (data not shown) and the general enrichment of $\delta^{15}\text{N}$ from the past to the present (Figures 5 and 6). Excluding the data from the sapwood rings removes the relationship in the Rankine Islands site (all $r < 0.1$, $P > 0.5$), but there remains a significant ($P < 0.01$) positive correlation in 4 of the 6 trees from the Lucy Islands site ($r > 0.44$) between percentage N and $\delta^{15}\text{N}$ enrichment.

Differences in average yearly precipitation and temperature could also be expected to influence relative tree growth. Yearly precipitation and tree growth were correlated ($P < 0.05$) in 4 of the 12 trees (Lc1bb, Lc3n, Lc5bb, and Rk8sbb), but in each of these, there was an inverse relationship. Yearly temperature and growth

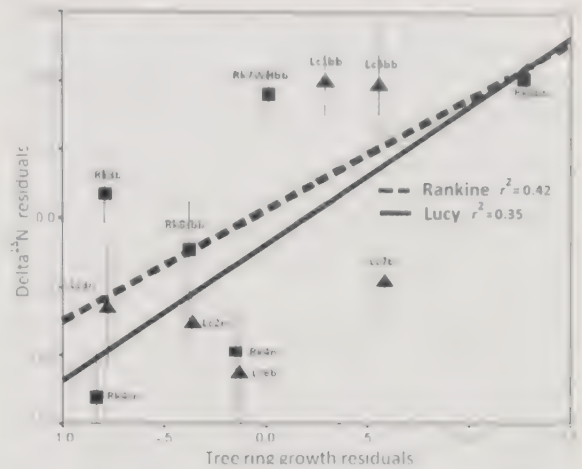


FIGURE 8. Relationship between average residuals for yearly tree growth and residuals of nitrogen isotope signatures on two seabird colonies (one on the Lucy Islands and one on the Rankine Islands), coastal British Columbia. Residuals extracted from linear regression between $\delta^{15}\text{N}$ and year of growth separated for locality (see Figures 4 and 5). Error bars show standard deviation. Tree code shows relative seabird burrow abundance at base of tree: n—no burrows; b—1 or 2 burrows; bb— >10 burrows.

were significantly positively correlated in three trees (Lc2n, Lc3n, and Lc5bb) and negatively correlated in Rk7whbb ($P < 0.05$). Overall comparisons (ANOVA with temperature and precipitation as covariates) yielded a significant negative effect for precipitation and growth ($F = 12.4$, $P < 0.001$) and no effect for temperature and growth ($F = 2.1$, $P > 0.15$).

We also examined growth in relation to the Pacific Decadal Oscillation for all the trees. Two of the 12 trees (one on each island) showed a significant correlation ($P < 0.01$) and in both cases it was negative.

Discussion

We evaluated the potential application of tree ring growth and nitrogen signatures as indicators of current and historical trends in seabird activity. Because the amount of seabird guano deposited in a colony should on average reflect the abundance and density of seabird activity, we predicted that yearly radial growth of trees would be accentuated in regions of high burrow density. Our data are consistent with this prediction and are similar to previous studies of seabird colonies in Japan (Mizota 2009; Mizota et al. 2011).

Statistical removal of tree size, which exhibits a modest positive association with yearly growth, did not undo the spatial associations with seabird burrow occurrence. Consequently, we predicted that historical differences in growth rate among trees from high burrow densities relative to nearby control trees where burrows were absent should in part reflect general differences in seabird activity. Based on this, we infer that, at the Lucy Islands site, there was a substantive reduction in seabird activity from 1920 to the 1960s and a partial

rebound in the late 1960s and early 1970s, followed by a continued decline to the 1990s. This may be correlated with the general reduction in seabird numbers observed in more southern colonies over the last century (Harfenist et al. 2002; Gaston et al. 2009), but the apparent decline might also be associated with human disturbance, such as road construction in the forest habitat during the 1900s (Graham 1986).

Corresponding data from the Rankine Islands site show a trend consistent with the Lucy Islands site for the spatial data, but for temporal data, trees from both low and high burrow microsites exhibited a 10- to 15-year periodicity in growth over the same time period and might reflect climatic influences on seabird nesting densities (for example, Bertram et al. 2009).

Seabird guano is greatly enriched in ^{15}N (Mitzutani and Wada 1988), and we predicted that ^{15}N enrichment would occur at higher levels in trees from regions of high burrow density. This was confirmed in both colonies and is concordant with other research on ground vegetation in California and Alaskan seabird colonies (Polis et al. 1997; Anderson and Polis 1998; Anderson et al. 2008; Wainright et al. 1998) and tree-ring analyses from seabird colonies in New Zealand (Holdaway et al. 2007) and Japan (Mizota 2009; Mizota et al. 2011). Enrichment of $\delta^{15}\text{N}$ in the sapwood ranged from approximately 10‰ in the non-burrow sites to 17‰ where burrows were prevalent. The latter enrichment is about 10‰ higher than that observed in tree rings from salmon rivers (Reimchen et al. 2003) but is comparable to levels observed in soil and foliar tissue from seabird colonies (Barrett et al. 2005; Wait et al. 2005; Mizota 2009).

Our observation of a major reduction in growth of trees from 1930 to the recent past from the locations with high burrow densities at the Lucy Islands site led us to suspect that ^{15}N would also decrease over the same time period. But, in complete contrast to this prediction, there was a general increase in ring $\delta^{15}\text{N}$ enrichment in 9 of 10 trees, common trends that were independent of both seabird burrow density and current size of trees.

Similar temporal increases in isotopic signatures have been reported in studies unrelated to seabirds (Feliksik and Wilczyński 2007; Weber et al. 2008; Couto-Vázquez and González-Prieto 2010)—but see Penuelas and Estiarte (1997)—including the multiple trees on salmon rivers from throughout coastal British Columbia (TER, unpublished data). Such geographically broad temporal trends suggest large-scale changes in nitrogen sources. For example, total nitrogen levels have increased over the last 100 years throughout much of the globe (Vitousek et al. 1997). This could have contributed to our trends if $\delta^{15}\text{N}$ enrichment also increased, yet recent empirical data from nitrate in Greenland ice cores show the opposite trend, as there has been a progressive decrease in ^{15}N from atmospheric deposition over the last 300 years (Hastings et al.

2009). Alternatively, the common trends among the trees could relate to size-related changes in nitrogen cycling. Weber et al. (2008) suggest that lower $\delta^{15}\text{N}$ enrichment in younger trees is the result of their access to the needle litter in surface soils rather than the deeper nitrogen sources, which are $\delta^{15}\text{N}$ enriched as a consequence of decomposition in the soils.

Perhaps, independent of soil depth, the total availability of the nitrogen pool is relevant, as higher input of nitrogen will result in greater fractionation and reduced uptake of ^{15}N (Handley et al. 1999). Consequently, if saplings or other small trees are exposed to levels of nitrogen adequate for larger counterparts but surplus to their own requirements, increased fractionation would be expected. This might contribute to the $\delta^{15}\text{N}$ depletion observed in the younger ages in the trees.

Our comparisons of $\delta^{15}\text{N}$ depletion in two saplings and their much larger counterparts at the same microsite were consistent with the suggestion that smaller trees show greater isotopic fractionation than their large counterparts. Although we estimated a calibration of about 0.045‰ per cm of tree, this did not substantially modify the increase in $\delta^{15}\text{N}$ signatures over the last 70 years. Currently, our data are not sufficient to identify whether these increases are atmospheric or more explicitly associated with seabird activity. The positive correlation between isotopic signatures and growth rate suggests access to an increased nitrogen pool.

Seabird populations are generally thought to have suffered a substantive decline over the last century, including those from the north Pacific (Campbell et al. 1990; Harfenist et al. 2002; Gjerdrum et al. 2003; Bertram et al. 2009; González-Solis and Shaffer 2009; International Union for Conservation of Nature 2009; Wolf et al. 2010). In British Columbia, seabird numbers have been monitored at several locations over the last three decades and show a slight reduction in the southern regions and a slight positive trend in northern British Columbia (Gaston et al. 2009).

Although the number of trees sampled in this study is small, the results show major heterogeneity in tree ring growth and nitrogen signatures over microgeographical gradients in abundance of seabird burrows. In this context, the growth data but not the nitrogen isotope data for the Lucy Islands site suggest a substantial reduction in seabird abundance over the last century (Gaston et al. 2009) but not for the more distant Rankine Islands colony in the Haida Gwaii archipelago, where temporal oscillation in activity is suggested.

These preliminary results, which are the first application of tree growth and isotopic proxies to seabird colonies in western Canada, supplement other recent studies on seabird activity in the western Pacific (Holdaway et al. 2007; Mizota et al. 2011). Despite the unresolved issues, such as nitrogen translocation (Balster et al. 2009), climatic variability (Bertram et al. 2005),

and trophic differentiation among alcids, we feel a broader coring grid with appropriate choice of target and adjacent control trees will provide seabird researchers with an additional tool to estimate the historical chronology and spatial distribution of seabird activity within and among colonies.

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Ecological and Geographical Separation of Three Varieties of *Sporobolus vaginiflorus* (Poaceae) in Eastern Ontario

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Field and herbarium studies of the three varieties of *Sporobolus vaginiflorus* (var. *inaequalis*, var. *vaginiflorus*, and var. *ozarkanus*) in eastern Ontario found that (1) there is a strong tendency for the varieties to occur alone; (2) var. *inaequalis* occurs primarily on roadside gravels, river shores, and granite barrens and is the only variety associated with acid as well as alkaline substrates; and (3) both var. *vaginiflorus* and var. *ozarkanus* are confined to alvar landscapes but occupy different geographical regions. The ecological and geographical differentiation of these taxa supports their taxonomic recognition and the protection of alvar landscapes to conserve subspecific variants.

Key Words: *Sporobolus vaginiflorus*; *Sporobolus vaginiflorus* var. *vaginiflorus*; *Sporobolus vaginiflorus* var. *inaequalis*; *Sporobolus vaginiflorus* var. *ozarkanus*; Poaceae; ecology; distribution; alvar; granite barren; taxonomy; classification; identification; Ontario

The three annual varieties of *Sporobolus vaginiflorus* (Torr. ex A. Gray) Alph. Wood (Sheathed Dropseed) that occur in eastern Ontario and throughout much of eastern North America include var. *inaequalis* Fernald, var. *ozarkanus* (Fernald) Shinnery, and var. *vaginiflorus*. These varieties were accepted by Fernald (1933, 1950) and Dore and McNeill (1980). Dore and McNeill (1980) reported distributional differences but did not relate them to ecology. There has been no further study of distributional differences, and more recent authors have generally accepted two taxa (vars. *vaginiflorus* and *ozarkanus*), placing var. *inaequalis* as a synonym of var. *vaginiflorus* (Peterson et al. 2003).

The regional study reported here aims to provide a better understanding of the ecology and distribution of the varieties of *Sporobolus vaginiflorus* in eastern Ontario and a more informed classification.

Methods

Three procedures were employed to gather information on the ecology and distribution of the three taxa.

(1) Co-occurrence data

Two hundred individual plants at each of the 49 sites (up to 1 acre each (4046.86 m²), including 4 river shores, 23 alvars (areas of flat, naturally more or less open limestone), and 22 roadsides), were studied and identified in the field in August to November 2009 in order to provide information on co-occurrence. Representative voucher specimens for each taxon were collected from most sites and deposited at the National Collection of Vascular Plants, Agriculture and Agri-Food Canada, Ottawa (DAO, acronyms follow Thiers 2013).

(2) Habitat information from specimens

All specimens of *Sporobolus vaginiflorus* from eastern Ontario in the herbaria at the National Herbarium of

Canada, Canadian Museum of Nature, Ottawa (CAN), at the National Collection of Agriculture and Agri-Food Canada, Ottawa (DAO), and at the Fowler Herbarium, Biology Department, Queen's University, Kingston (QK), were identified and associated with river shore, alvar, roadside, and granite habitats based on available specimen label data, in order to characterize the habitats of the varieties using frequency histograms.

(3) Geographic distribution

All herbarium specimens of the three varieties were plotted on maps of eastern Ontario showing alvar landscapes to provide a visual association and to expand use of the data for specimens lacking habitat information. Alvar landscapes for the latter application were derived from a plot of undulating, 1–3% slope class landscapes with melanic brunisol soils with calcareous clay or loam parent material (Agriculture Canada 1989). This provided reasonable boundaries for the Smiths Falls (central on the maps) and Napanee (lower left on maps) limestone plains as they have been portrayed previously (Chapman and Putnam 1984). The herbarium data included 184 (Appendix 1) specimens, of which 83 were referable to var. *inaequalis*, 46 to var. *ozarkanus*, and 55 to var. *vaginiflorus*. Plants were identified using a newly developed key to northeastern North American *Sporobolus* taxa based on Dore and McNeill (1980):

- 1a. Lemmas smooth, hairless; white, lacking grey mottling but sometimes suffused with purple near their tips if exposed *Sporobolus neglectus*
- 1b. Lemmas with minute antrorse hairs, or without; whitish with grey mottling, except those near the long exposed tips of a terminal inflorescence which may become uniformly dark reddish-purple 2

- 2a.

Paleas of lower ensheathed florets on any inflorescences long, acute, and prolonged beyond the lemma (1.2–2 times as long as the lemma)

3
- 2b.

Paleas of lower ensheathed florets on any inflorescences mucronate, only slightly exceeding the lemma (less than 1.2 times as long as the lemma)

5
- 3a.

Lemma and palea without antrorse hairs *S. vaginiflorus* var. *inaequalis* × *ozarkanus*

?
- 3b.

Lemma and palea with antrorse hairs

4
- 4a.

Paleas of ensheathed florets long, narrowly acute, or acuminate and 1.2–2 times as long as the lemma

S. vaginiflorus var. *inaequalis*
- 4b.

Paleas of ensheathed florets acute or rounded and 1.1–1.2 times as long as the lemma?

S. vaginiflorus var. *inaequalis*
× var. *vaginiflorus*
- 5a.

Lemmas strigose with antrorse hairs (shiny microhairs visible in directed light)

S. vaginiflorus var. *vaginiflorus*
- 5b.

Lemmas not strigose

S. vaginiflorus var. *ozarkanus*

Results

(1) Co-occurrence

At 42 of 49 sites (85.7%), only one variety of *Sporobolus vaginiflorus* was present. There were 5 sites (10.2%) with two varieties (in all cases var. *inaequalis* and var. *ozarkanus*) and only 2 sites with all three varieties (4.1%). There is a clear tendency for varieties to occur alone based on examination of a total of 9800 individuals at 49 sites (Appendix 1, Table 1).

(2) Habitat information from specimens

Of the three taxa, *Sporobolus vaginiflorus* var. *inaequalis* has the broadest ecological amplitude based on specimen label data (Figure 1), but it occurs primarily along roads. The granite and sand habitats are often acidic but roadsides and other habitats may have neutral or alkaline substrates. In eastern Ontario, var. *ozarkanus* is confined to natural habitats of alvars, and var.



FIGURE 1. Histograms showing the number of plants of the three different varieties of *Sporobolus vaginiflorus* (var. *inaequalis*, var. *vaginiflorus*, and var. *ozarkanus*) in different habitats based on specimens at CAN, DAO, and QK.



FIGURE 2. Collection sites of *Sporobolus vaginiflorus* var. *inaequalis* in eastern Ontario based on specimens examined at CAN, DAO, and QK. The alvar landscapes are lightly shaded, and the map portrays primary drainage and county boundaries.



FIGURE 3. Collection sites of *Sporobolus vaginiflorus* var. *ozarkanus* in eastern Ontario based on specimens examined at CAN, DAO, and QK. The alvar landscapes are lightly shaded, and the map portrays primary drainage and county boundaries.



FIGURE 4. Collection sites of *Sporobolus vaginiflorus* var. *vaginiflorus* in eastern Ontario based on specimens examined at CAN, DAO, and QK. The alvar landscapes are lightly shaded, and the map portrays primary drainage and county boundaries.

vaginiflorus occurs mostly in alvars and on river shores (Figure 1). Some plants attributed to var. *vaginiflorus* from river shore habitats, such as Shirleys Bay on the Ottawa River, are intermediate between var. *inaequalis* and var. *vaginiflorus*.

(3) Geographic distribution

The widespread occurrence of *Sporobolus vaginiflorus* var. *inaequalis* (Figure 2) corresponds to the map produced by Dore and McNeill (1980, map 164). Both var. *vaginiflorus* and var. *ozarkanus* have a more extensive distribution in eastern Ontario than was shown by Dore and McNeill (1980), but the seminal observation by Dore and McNeill (1980)—that the distribution was restricted—is supported (Figures 3 and 4). The distinctive geographic distributions of these two varieties in eastern Ontario are associated with alvar landscapes, but the two varieties occur largely in different subunits of those landscapes, var. *vaginiflorus* occurring in the Napanee and northern Smiths Falls plains and var. *ozarkanus* occurring in the Napanee and southern Smiths Falls plains. The much more extensive distribution of var. *inaequalis* is not surprising, considering the variety of habitats that it occupies.

Discussion

The strong tendency for varieties of *Sporobolus vaginiflorus* to occur alone was anticipated, since many herbarium sheets have numerous individual plants and yet more than one taxon was mounted on a sheet less than 1% of the time. To a large extent, the tendency to occur alone may be due to the demonstrated differences in ecology. Varieties and subspecies may often be ecologically different, as species are (Van Valen 1976; Grant 1992), with some exceptions (Shmida and Ellner 1984; Scheffer and van Nes 2006). As a consequence, ecological differentiation may be useful in supporting the recognition of infrataxa. Since the three varieties are ecologically and morphologically distinct, they are more than likely genetically unique. Observations elsewhere in the range of *S. vaginiflorus* are needed to confirm that recognition of the varieties is warranted.

Acknowledgements

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APPENDIX 1. Specimens examined that are the basis for the mapping of the varieties of *Sporobolus vaginiflorus* in eastern Ontario. Under each variety, the herbarium sheet citations are organized by collection date. Sheets lacking dates are listed at the end. An additional list of site records by the author (not vouchered) on file at DAO (also mapped) is included. The latitudes and longitudes are generally accurate to within 0.5 km of collection sites for collections after 1970 but may be up to 5 km distant from collection sites prior to that date, when it was more common to give general locations. The approximate latitude and longitude were added to the label data later for mapping purposes.

Sporobolus vaginiflorus* var. *inaequalis

Specimens. CANADA. Ontario: Merivale, 45.3568, -75.7369, 30 September 1935, *W.G. Dore* 223 (DAO 221100); Merivale, 45.3568, -75.7369, 30 September 1935, *W.G. Dore* 224 (DAO 221101); Merivale, 45.3568, -75.7369, 18 September 1936, *W.G. Dore* 405 (DAO 221102); Bells Corners, 45.3291, -75.8055, 8 October 1936, *W.G. Dore* 406 (DAO 221099); Galetta, 45.4256, -76.256, 3 September 1943, *W.G. Dore & H. Groh* 5069 (DAO 221042); Ennis Point, 45.3864, -75.8938, 3 September 1948, *W.G. Dore & A.J. Breitung* 9277 (DAO 221097); Innis Point, 45.3864, -75.8938, 3 September 1948, *W.G. Dore & A.J. Breitung* 9298 (DAO 221098); Sand Point [3 km SSE of Westmeath] 45.8000, -76.9166, 19 September 1948, *W.G. Dore* 9765 (DAO 221095); Shirley's Bay, 45.3658, -75.8828, 7 September 1952, *W.G. Dore* 14035 (DAO 221047); Fermoy, 44.6159, -76.5719, 2 October 1952, *W.G. Dore & J.M. Gillett* 17569b (DAO 221089); Westport, 44.6852, -75.7984, 2 October 1959, *W.G. Dore & J.M. Gillett* 43870 (DAO 596334); 8 miles of Eganville, 45.4279, -77.0403, 22 August 1960, *W.G. Dore* 18344 (DAO 221090); Chaffeys Road, 44.622, -76.2667, 10 September 1960, *R. Hainault* 1335 (DAO 221091); Chaffeys Road, 44.622, -76.2667, 10 September 1960, *R. Hainault* 1335 (DAO 839503); S. Crosby Twp., road to Chaffeys 1 mile from Rd. 15, 44.5808, -76.3172, 10 September 1960, *R. Hainault* 1335 (QK 49047); Prescott (3 miles NE of centre), 44.7095, -75.5138, 14 September 1960, *W.G. Dore* 18582 (DAO 221076); Prescott (3 miles NE of centre), 44.7119, -75.5169, 14 September 1960, *W.G. Dore* 18582 (QK 49046); Prescott, 44.7095, -75.5138, 24 September 1960, *W.G. Dore* 18703 (DAO 221075); Prescott (3.2 miles SW), Hwy. 2 along river shore, 44.6814, -75.5559, 24 September 1960, *W.G. Dore* 18703 (QK 49045); Mallorytown, 44.4544, -75.8805, 5 September 1961, *W.G. Dore* 19603 (DAO 221072); Mallorytown Landing, 44.4544, -75.8591, 6 September 1961, *W.G. Dore* 19657 (DAO 221073); N of Brockville, 44.6178, -75.7106, 6 September 1962, *W.G. Dore* 20065 (DAO 221088); Petawawa (one mile WNW), 45.9015, -77.3057, 21 July 1965, *W.G. Dore & T.C. Brayshaw* s.n. (CAN 569754); Rear of Leeds & Lansdowne Twp., 3 km NE of Lyndhurst, 44.5497, -76.1231, 30 September 1966, *Beschel* 15758 (QK 62927); Bedford Twp., Frontenac Park, Little Clear Lake, 44.55, -76.5000, 1 September 1968, *R. Hainault & I. Macdonald* 4718 (QK 97376); Camden East alvar, 44.3342, -76.7929, 26 August 1969, *Hainault & MacDonald* 5329 (DAO 839507); Camden Twp., Camden East alvar, NE sector, 44.3342, -76.7929, 26 August 1969, *R. Hainault & I. Macdonald* 5329 (QK 90839); Highway to Barry's Bay and S exit to Killaloe, 45.5654, -77.4205, 27 September 1970, *M.I. Moore* 5285 (CAN 569753); Belleville, Thurlow Twp., Canadian Pacific Railway (CPR) abandoned cinder track, 44.2567, -77.3697, 6 October 1970, *S. Vander Kloet* 90 (QK 97721); August–October North Algoma Twp., N of Golden Lake, Thomas Mountain, 45.6167, -77.4000, 14 September 1978, *J.M. Gillett & M.J. Shechpanek* 17988 (CAN 417855); Bishops Mills, 44.8725, -75.7015, 28 August 1979, *W.G. Dore* 493 (DAO 689350); Nepean, Barrhaven, 1 km SW of intersection of Fallowfield and Greenbank Rds., 45.2833, -75.75000, 16 September 1979, *D.F. Brunton, J.D. Lafontaine & C. Frankton* 1980 (CAN 490172); Ottawa, 1030 Derby Street, 45.3786, -75.7322, 17 September 1979, *D.F. Brunton* 1981 (CAN 452556); September, August, August Nepean, 45.3833, -78.9500, 11 September 1980, *D.F. Brunton* 2730 (DAO 282956); Point Pelee National Park parking lot, by marsh boardwalk, 41.9678, -82.5308, 17 October 1981, *D.F. Brunton* 3509 (CAN 479997); Petawawa, Petawawa Fish Hatchery, Laurentian Drive, 45.8833, -77.2333, 28 July 1982, *D.F. Brunton* 3653 (CAN 470169); Front of Leeds & Lansdowne Twp., Fitzsimmons Mountain, 44.3722, -76.0333, 4 September 1982, *S.J. Darbyshire, D.A. Sutherland, & M. Oldham* 1738 (CAN 468804); Gloucester, the Queensway (Hwy. 417), SE side of Montreal Road interchange, 45.4500, -75.5833, 9 September 1982, *D.F. Brunton* 3975 (CAN 470411); E of Marionville, 45.1902, -75.3306, 15 June 1983, *S.J. Darbyshire & C. Hanrahan* 1878 (DAO 353135); Bell Corners, 45.3291, -75.8055, 29 August 1983, *S.G. Aiken* s.n. (DAO 398739); Maxville exit on hwy 417, 45.3347, -74.9207, 31 August 1983, *S.G. Aiken & S.J. Darbyshire* 2601 (DAO 376329); 3 km W of Embrun, 45.2683, -75.329, 3 September 1983, *S.J. Darbyshire* 2091 (DAO 396191); Russell Twp., 3 km west of Embrun north of Castor River, 45.2694, -75.3125, 3 September 1983, *S.J. Darbyshire* 2091 (CAN 531276); Horton Twp., 3 km SW of Chenaux, 45.5625, -76.6666, 5 September 1983, *S.J. Darbyshire* 2112 (CAN 531275); Rideau River Provincial Park north of Kemptville, 45.0583, -75.6694, 11 September 1983, *S.J. Darbyshire* 2117 (CAN 531272); Ottawa, NCC driveway along Rideau Canal [Queen Elizabeth Drive] near Pretoria bridge, 45.4372, -75.679, 6 September 1984, *S.J. Darbyshire* (CAN 531283); Howard Twp., Hwy 401 at turn-off for Ridgetown, 42.4833, -81.9166, 20 September 1984, *S.J. Darbyshire* 2443 (CAN 531286); Ottawa, NCC driveway [Queen Elizabeth Drive], 45.3943, -75.6957, 22 September 1984, *W.G. Dore* 936 (DAO 452166); Hwy. 16 and McGovern Road, SE of Kemptville, 44.9745, -75.6069, 14 June 1985, *W.G. Dore* 973 (DAO 444402); Westmeath, 45.8000, -76.9166, 22 September 1985, *S.J. Darbyshire, A.A. & S.A. Reznicek, P.M. Catling & V. Brownell* 2887 (DAO 551870); Westmeath Twp., Ottawa River, Sand Point, 45.8000, -76.9166, 22 September 1985, *S.J. Darbyshire, A.A. & S.A. Reznicek, P.M. Catling & V. Brownell* 2887 (CAN 500148); Bruce pit, 45.3249, -75.7985, 6 October 1985, *S.J. Darbyshire and S.G. Aiken* 2896 (DAO 551871); Nepean, Bells Corners, Bruce pit, 45.325, -75.8083, 6 October 1985, *S.J. Darbyshire & S.G. Aiken* 2896 (CAN 531281); NW of Mountain, 44.7500, -76.8666, 21 August 1986, *S.G. Darbyshire & C. Hanrahan* 3182 (DAO 465544); Little Clear Lake, 44.555, -76.4996, 1 September 1986, *Hainault & MacDonald* 4718 (DAO 839506); Rideau Twp., 13 km S of

Richmond, Cedar Grove Picnic Site at edge of corn field, 45.0722, -75.8306, 14 September 1986, *S.J. Darbyshire & V.P. Shepstone* 3202 (CAN 520897); Gloucester Twp., on Hawthorne Road extension, 45.3000, -75.55, 1 October 1986, *A.W. Dugal & M. Camfield* 2282 (CAN 522505); Clarendon, 44.8714, -76.7158, 30 August 1987, *S.J. Darbyshire* 3606 (DAO 575637); Oso Twp., 1.5 km west of Clarendon Station, 44.8666, -76.3833, 30 August 1987, *S.J. Darbyshire* 3606 (CAN 529764); Asselstine alvar, 44.2583, -76.725, August 1988, *P.M. Catling s.n.* (DAO 580227); South Sherbrooke Twp., 3 km west of Christie Lake, 1 km N of Tay River, near Canadian Pacific Railway (CPR) trestle, 44.7833, -76.5000, 21 August 1989, *M.J. Shchepanek, A.W. Dugal, R.R. Ireland & L.M. Ley* 8521 (CAN 542960); Ottawa River near Baskin's Beach, 45.4823, -76.0209, 4 October 1991, *J.M. Gillett* 18058 (CAN 562960); Kaladar Jack Pine Area of Natural and Scientific Interest (ANSI), 44.607, -77.157, 26 September 1993, *V.R. Brownell s.n.* (DAO 671186); Morris Island Conservation Area, Ottawa River, 45.4500, -76.2833, 30 August 1997, *W.J. Crins, H.M. Runtz & D. Runtz* 10589 (DAO 865841); Canadian Forces Base (CFB) Petawawa, 1 km NE of Montgomery Lake, 100 m W of tower at top of Montgomery Tower Road, 46.9416, -77.55, 25 September 1998, *D.F. Brunton* 13810 (CAN 585313); Mellon Lake [9.5 km S of Kaladar], 44.5596, -77.1116, 31 August 2004, *S.J. Darbyshire and C. Hanrahan* 5252 (DAO 797766); Constance Bay sand hills, Bishop Davis Road and Allbirch Road, 45.4916, -75.0875, 9 October 2007, *S.J. Darbyshire & C.V. Hanrahan* 5595 (DAO 877548); Loyalist Twp., Odessa, west of Bridge St., 44.2663, -76.7104, 26 August 2009, *D. Kristensen* (QK 139024); Odessa alvar, 44.2663, -76.7104, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 844864); Deseronto Airport, 44.1776, -77.1195, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845581); Camden East, 44.3342, -76.7929, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845605); Camden East, 44.3342, -76.7929, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845661); Camden East, 44.3342, -76.7929, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845608); Lonsdale, 44.2531, -77.1221, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845599); sandy edge of Slack Road, Ottawa, 45.3198, -75.7357, 6 November 2009, *P.M. Catling s.n.* (DAO 845565); Marlborough Forest, 45.0775, -75.8118, 7 November 2009, *P.M. Catling s.n.* (DAO 845559); Hwy. 417 W of Boundary Road, 45.3548, -75.4678, 8 November 2009, *P.M. Catling s.n.* (DAO 845566); Shirleys Bay at foot of Rifle Road, 45.3658, -75.8828, 10 November 2009, *P.M. Catling s.n.* (DAO 845568); Hwy. 41 N of Maguire, 44.5688, -77.1165, 11 November 2009, *P.M. Catling s.n.* (DAO 845576); Innis Point near tip, 45.3864, -75.8938, 15 November 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845571); Innis Point N side, 45.3915, -75.8981, 15 November 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845573); Westport, 44.6852, -75.7984, *s.d., W.G. Dore & J.M. Gillett s.n.* (DAO 221092); Sandy Hill, Ottawa, 45.4252, -75.6735, *s.d., I. Zgierska s.n.* (DAO 460483).

Sight records. CANADA. Ontario: Hwy. 417 near Vars, 45.386, -75.3486, 8 November 2009, *P.M. Catling*; Hwy. 417 E of Casselman, 45.364, -75.8726, 8 2009, *P.M. Catling*; Hwy. 17 at Hawkesbury, 45.5951, -74.6157, 8 2009, *P.M.*

Catling; Merivale Rd. median S of Baseline Rd. near Campiano Drive, 45.3568, -75.7369, 8 November 2009, *P.M. Catling*; Hwy. 7 W of Ottawa, 45.2605, -75.9717, 22 November 2009, *P.M. Catling*; 12 November 2009, *P.M. Catling*; Hwy. 7 near Brooke, 44.8544, -76.4431, 12 November 2009, *P.M. Catling*; Hwy. 7 at Swamp Road, 44.7544, -76.8527, 12 November 2009, *P.M. Catling*; Kaladar, 44.6482, -77.1217, 12 November 2009, *P.M. Catling*; W of Arnprior, 45.4468, -76.5566, 22 November 2009, *P.M. Catling*; Centennial Road at Black Donald Lake, 45.223, -76.9574, 22 November 2009, *P.M. Catling*; Centennial Road E of LeClaire Lane, 45.1877, -76.9997, 22 November 2009, *P.M. Catling*; Hwy. 28 at Denbigh, 45.1429, -77.2663, 22 November 2009, *P.M. Catling*; Hardwood Lake Junction [km W of Renfrew], 45.2129, -77.4401, 22 November 2009, *P.M. Catling*; Hwy. 515 near Latchford Bridge, 45.2951, -77.4473, 22 November 2009, *P.M. Catling*; Hwy. 512 25 km WSW of Eganville, 45.4339, -77.3162, 22 November 2009, *P.M. Catling*; Hwy. 417 near Renfrew, 45.4962, -76.6700, 22 November 2009, *P.M. Catling*; Hwy. 7 near Perth, 44.9091, -76.266,

Sporobolus vaginiflorus* var. *ozarkanus

CANADA. Ontario: 1.2 km SW of Odessa, 44.2613, -76.7263, 7 September 1917, *R.W. Hainault* 67-315 (DAO 220897); 1 km N of Asselstine, 44.2612, -76.7104, 17 November 1962, *R. Beschel et al.* 13632 (DAO 221124); Enes-town Twp., 3 km S of Odessa near Asselstine, 44.2444, -76.7314, 17 November 1962, *Beschel et al.* 13632 (QK 54483-1); Hungerford Twp., N end of Dry Lake, 44.4215, -76.8684, 14 September 1968, *R. Beschel* 17040 (QK 80595); Ernestown Twp., 2.5 miles S of Odessa, 44.2769, -76.7225, 19 September 1968, *K.J. Crawford* 147 (QK 114247); Camden Twp., Camden East alvar, 44.3342, -76.7929, 4 October 1968, *S.P. Vander Kloet* 2617 (QK 82077); Rideau Twp., Marlborough Forest, 45.0333, -78.8111, 21 November 1981, *S.J. Darbyshire* 1602 (CAN 465434); Montagne Twp., lot 5, Conc. X, 45.0444, -75.9500, 16 October 1983, *S.J. Darbyshire* 2136 (CAN 531277); Ottawa, approx. 0.25 mile E of Hwy. 31, W of Hawthorne Road, 45.3000, -75.33, 23 October 1984, *A.W. Dugal* 1859 (CAN 501851); Brighton Twp., Presqu'île Provincial Park, NE side of the main road opposite 2nd Beach Road, 44.0083, -77.7333, 12 September 1986, *D.F. Brunton* 7024 (CAN 537011); Thurlow Twp., east of Belleville on the Bay of Quinte, Point Anne, 44.1583, -77.2833, 5 September 1987, *S.J. Darbyshire, M.J. Oldham, D.A. Sutherland, et al.* 3610 (CAN 529768); Thurlow Twp., 4 km E of Belleville, Point Anne Area of Natural and Scientific Interest (ANSI), 44.1667, -77.2833, 14 September 1990, *I.D. Macdonald* 21903 (QK 133807); Camden East alvar, 44.3342, -76.7929, 25 August 1993, *T. Norris* 416 (DAO 685180); Presqu'île Park, 43.9971, -77.7293, 20 September 1994, *S. Blaney* (DAO 688881); Camden East alvar, 44.3342, -76.7929, 19 September 1995, *M.J. Oldham & W.D. Bakowsky* 18233 (DAO 688980); Mohawk Cemetery, 44.1813, -77.0816, 19 September 1995, *M.J. Oldham & W.D. Bakowsky* 18245 (DAO 688983); Point Anne E of Belleville, 44.1575, -77.2949, 20 October 1995, *M.J. Oldham & W.D. Bakowsky* 18382 (DAO 701808); Odessa alvar, 44.2663, -76.7104, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 844864); Odessa Alvar, 44.2663, -76.7104, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 843818);

Point Anne upper area, W of Belleville, 44.1677, -77.3012, 18 October 2009, *P.M. Catling & B. Kostiuk* (DAO 845583); Point Anne lower area, West of Belleville, 44.1575, -77.2949, 18 October 2009, *P.M. Catling & B. Kostiuk* (DAO 845533); Deseronto Cemetery, 44.1813, -77.0816, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 844865); Deseronto Cemetery, 44.1813, -77.0816, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845531); Deseronto Airport, 44.1776, -77.1195, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845532); Deseronto Airport, 44.1776, -77.1195, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845519); Odessa alvar, 44.2663, -76.7104, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 844863); Odessa alvar, 44.2663, -76.7104, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845604); Camden East, 44.3342, -76.7929, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845554); Lonsdale alvar, 44.2531, -77.1221, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845601); Lonsdale alvar, 44.2531, -77.1221, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845660); Lonsdale alvar, 44.2531, -77.1221, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845597); Lonsdale alvar, 44.2531, -77.1221, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845598); Lonsdale alvar, 44.2531, -77.1221, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845602); Camden East, 44.3342, -76.7929, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845610); Camden East, 44.3342, -76.7929, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845556); Marlborough Forest, 45.0775, -75.8118, 7 November 2009, *P.M. Catling* (DAO 845557); Dwyer Hill Road N of Burritts Rapids, 45.0267, -75.8582, 7 November 2009, *P.M. Catling* (DAO 845561); Flood Road, 45.0352, -75.8134, 7 November 2009, *P.M. Catling s.n.* (DAO 845575); Flood Road 2, Marlborough Forest, 45.0406, -75.8100, 7 November 2009, *P.M. Catling s.n.* (DAO 845574); Mill Street S of Merrickville, 44.8882, -75.8198, 12 November 2009, *P.M. Catling s.n.* (DAO 845580); N of North Augustusta, 44.7809, -75.7571, 12 November 2009, *P.M. Catling s.n.* (DAO 845579); Asselstine alvar, 44.2612, -76.7104, 22 November 2009, *P.M. Catling s.n.* (DAO 844681); Asselstine alvar, 44.2612, -76.7104, 22 November 2009, *P.M. Catling s.n.* (DAO 844680); Grant Side Road [15 km SE of Arnprior], 45.3608, -76.1794, 22 November 2009, *P.M. Catling s.n.* (DAO 843931); Dwyer and O'Neil Roads [20 km NNE of Smiths Falls], 45.0792, -75.9058, 28 November 2009, *P.M. Catling s.n.* (DAO 843935); Franktown, 45.0096, -76.0529, 28 November 2009, *P.M. Catling s.n.* (DAO 843936).

Sight record. CANADA. Ontario: O'Neil Road [13.5 km NW of BurriRapids], 45.08, -75.904, 28 2009, *P.M. Catling*.

Sporobolus vaginiflorus* var. *vaginiflorus

CANADA. Ontario: Thurlow Twp., Belleville, 44.2567, -77.3697, September 1871, *J. Macoun s.n.* (QK 55478); Britannia, 45.3715, -75.8038, September 1919, *Rolland-Germain 8023* (DAO 623680); Britannia, 45.3735, -75.7975, September 1919, *Fr. Rolland-Germain 8023* (CAN 355410); Kinburn, 45.354, -76.1901, 3 September 1943, *W.G. Dore & H. Groh 5072* (DAO 221046); Shirleys Bay, 45.3658, -75.8828, 13 September 1952, *W.G. Dore & D. Erskine 14094* (DAO 221048); Burnt Lands [5 km NE of Almonte], 45.2562, -76.1480, 22 November 1953, *C. Frankton 1489* (DAO

221045); Westboro, Ottawa, 45.382, -75.7767, 28 August 1955, *W.G. & K.M. Dore 16164* (DAO 221103); Huntley Twp., 5 km ENE of Almonte, 45.225, -76.195, 7 June 1969, *R. Beschell & E. Greenwood 17202* (QK 91964); Tyendinaga Twp., Highway 401, W of Salmon River, 44.2287, -77.1662, 1 May 1970, *R. Beschell 100* (QK 97216); Burnt Lands, 45.2562, -76.1480, 8 September 1974, *P.M. Catling and S.M. McKay* (DAO 131201); Huntley Twp., Burnt Lands NE of Almonte, 45.25, -76.1000, 8 September 1974, *P.M. Catling & S.M. McKay* (CAN 394675); Burnt Lands, 3 miles NE of Almonte, N side of Hwy. 44, 45.2666, -76.15, 26 August 1978, *David White 1234* (CAN 433138); Ottawa River, Shirleys Bay, 1 km NW of Innis Point, 45.3833, -75.8833, 28 August 1980, *D.F. Brunton 2573* (CAN 455766); Almonte alvar, 45.2562, -76.148, 28 August 1983, *R. Hainault 8361* (DAO 839501); Braeside, 3.5 km NW of, 45.4763, -76.4485, 11 October 1983, *S.J. Darbyshire 2131* (DAO 383315); Malloy Bay, Ottawa River [7.5 km NE of Westmeath], 45.8666, -76.7943, 6 November 1983, *S.J. Darbyshire 2150* (DAO 396266); Westmeath Twp., North Front D, Ottawa River, Malloy Bay, 45.8666, -76.7944, 6 November 1983, *S.J. Darbyshire 2150* (CAN 543627); 3 km W of Panmure, 45.3166, -76.2333, 25 September 1985, *D.F. Brunton 6585* (DAO 452153); Sand Point, 1.5 km SW, 45.7833, -76.9166, 26 August 1987, *D.F. Brunton 7594* (DAO 572863); Clay Bank alvar, 45.3741, -76.4071, 6 October 1987, *S.J. Darbyshire 3642a* (DAO 575687); SE part of MacNab Twp., along border with Lanark County, 45.3833, -76.3833, 6 October 1988, *S.J. Darbyshire 3642A* (CAN 529796); Mohawk Cemetery, 44.1813, -77.0816, 19 September 1995, *M.J. Oldham & W.J. Bakowsky 18246* (DAO 688984); 6 km NNW of Lonsdale, 44.299, -77.1904, 19 September 1995, *M.J. Oldham & W.J. Bakowsky 18230* (DAO 701807); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge, & S. Chan* (DAO 844215); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844217); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844219); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844218); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844214); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844212); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844209); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844208); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844213); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844216); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844210); Ramsay alvar (*Thyrea* site), 45.2639, -76.1935, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844211); Ramsay alvar (Big Prairie), 45.2738, -76.1934,

14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844228); Ramsay alvar (Big Prairie), 45.2738, -76.1934, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844226); Ramsay alvar (Big Prairie), 45.2738, -76.1934, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844231); Ramsay alvar (Big Prairie), 45.2738, -76.1934, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844230); Ramsay alvar (Big Prairie), 45.2738, -76.1934, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844227); extension of Ramsay Concession 12, 45.2652, -76.189, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844220); extension of Ramsay Concession 12, 45.2652, -76.189, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844224); extension of Ramsay Concession 12, 45.2652, -76.189, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844225); extension of Ramsay Concession 12, 45.2652, -76.189, 14 October 2009, *G. Mitrow, P.M. Catling, I. McFetridge & S. Chan s.n.* (DAO 844223); Odessa alvar, 44.2663, -76.7104, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.*

(DAO 844864); Odessa alvar, 44.2663, -76.7104, 18 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 843818); Clay Bank alvar, 9th Concession at Barrie Road [Pakenham Twp., Ottawa], 45.3739, -76.4072, 25 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 843920); Department of National Defence (DND) alvar, Burnt Lands Provincial Park, 45.255, -76.1484, 25 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845578); Department of National Defence (DND) alvar, Burnt Lands Provincial Park, 45.255, -76.1484, 25 October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 845577); Burnt Lands E of Golden Line, 45.2488, -76.1417, October 2009, *P.M. Catling* (DAO 844688); Braeside, 45.4789, -76.4477, October 2009, *P.M. Catling & B. Kostiuk s.n.* (DAO 844687); Asselstine alvar, 44.2612, -76.7104, 22 November 2009, *P.M. Catling s.n.* (DAO 844682); Chartrand Island, Shirleys Bay, Ottawa River, 45.3848, -75.8973, *s.d.*, *J.M. Gillet s.n.* (DAO 220864); Beattie [Beatty] Point, 45.3658, -75.8828, *s.d.*, *H. Groh s.n.* (DAO 221041); Shirleys Bay, 45.3658, -75.8828, *s.d.*, *W.G. Dore s.n.* (DAO 221043); Shirleys Bay, *s.d.*, 45.3658, -75.8828, *W.G. Dore s.n.* (DAO 221044).

TABLE 1. Co-occurrence data for 200 plants at each of 64 sites (4 river shores, 23 alvars, and 22 roadsides). The data include the percentage of 200 plants examined of each taxon at each site and include 32 occurrences of *Sporobolus vaginiflorus* var. *inaequalis*, 18 of *Sporobolus vaginiflorus* var. *ozarkanus*, and 8 of *Sporobolus vaginiflorus* var. *vaginiflorus*.

		<i>Sporobolus vaginiflorus</i>			
	Latitude	Longitude	% var. <i>inaequalis</i>	% var. <i>ozarkanus</i>	% var. <i>vaginiflorus</i>
Roadsides, railways, gravel pits (22)					
	44.56880	-77.11654	100	0	0
	44.64820	-77.12171	100	0	0
	44.75440	-76.85267	100	0	0
	44.85436	-76.44313	100	0	0
	44.90908	-76.26596	100	0	0
	45.08001	-75.90396	80	20	0
	45.14285	-77.26627	100	0	0
	45.18773	-76.99974	100	0	0
	45.21290	-77.44009	100	0	0
	45.22298	-76.95741	100	0	0
	45.26049	-75.97174	100	0	0
	45.29506	-77.44725	100	0	0
	45.31976	-75.73569	100	0	0
	45.35482	-75.46777	100	0	0
	45.35680	-75.73687	100	0	0
	45.36068	-75.88069	100	0	0
	45.36397	-75.87257	100	0	0
	45.38600	-75.34857	100	0	0
	45.43386	-77.31621	100	0	0
	45.44675	-76.55659	100	0	0
	45.49621	-76.66999	100	0	0
	45.59506	-74.61571	100	0	0
Alvars (23)					
Smiths Falls Plain (15)					
	44.78088	-75.75705	0	100	0
	44.88815	-75.81976	0	100	0
	45.00958	-76.05291	0	100	0
	45.02667	-75.85820	0	100	0
	45.03521	-75.81342	0	100	0
	45.04058	-75.80996	0	100	0
	45.07749	-75.81175	43	57	0
	45.07924	-75.90578	0	100	0
	45.24879	-76.14172	0	0	100
	45.25621	-76.14804	0	0	100
	45.26390	-76.19350	0	0	100
	45.27380	-76.19340	0	0	100
	45.36080	-76.17938	0	100	0
	45.37413	-76.40706	0	0	100
	45.47886	-76.44771	0	0	100
Napanees Plain (8)					
	44.15751	-77.29488	0	100	0
	44.16769	-77.30115	0	100	0
	44.17756	-77.11947	45	55	0
	44.18126	-77.08159	0	100	0
	44.25310	-77.12210	39	61	0
	44.26120	-76.71037	55	30	15
	44.26626	-76.71037	38	40	22
	44.33420	-76.79290	53	47	0
Shore of the Ottawa River (4)					
	45.36583	-75.88284	100	0	0
	45.38639	-75.89383	100	0	0
	45.39148	-75.89811	100	0	0
	45.51126	-76.22361	100	0	0

Bird Behaviour on and Entanglement in Invasive Burdock (*Arctium* spp.) Plants in Winnipeg, Manitoba

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Burdocks (*Arctium* spp.) are invasive plants native to Eurasia. They produce their seeds within large burrs that adhere to vertebrates for seed dispersal, i.e., epizoochory. Small animals may become entangled in these burrs and die. Through active searches of natural areas in Winnipeg, Manitoba, from 2000 to 2005, we documented 29 songbirds entangled in burdock burrs and recorded observations of bird behaviour on burdock plants. We analyzed trends among birds found entangled by taxon, sex, age, migratory status, and season, and we compared them to observations of bird activity on burdock. Thirteen species of birds were found entangled. Most birds found entangled (62%) were warblers (Parulidae), but there were also species from five other families (<15% per family). There was no significant difference in the distribution of birds found entangled by sex or age. A significant proportion of birds found entangled were migrants, and the average number of birds found entangled per search visit differed significantly by season, with most birds found entangled in fall. By comparison, we recorded 34 species of birds ($n = 178$ observations) active on burdock plants. Warblers (38%) and sparrows (Emberizidae) (24%) were the most active, followed by small numbers of birds from eight other families (~9% per family). Species that were observed actively foraging on burdocks more often became entangled than those species observed only perching on burdocks. Species found entangled had a significantly lower body mass than species that were not found entangled but were active on burdocks. Overall, we suggest that small-bodied fall migrants that forage on burdock plants are most at risk of becoming entangled.

Key Words: burdock; *Arctium*; Downy Woodpecker; *Picoides pubescens*; Yellow-bellied Flycatcher; *Empidonax flaviventris*; Least Flycatcher; *Empidonax minimus*; Blue-headed Vireo; *Vireo solitarius*; Red-eyed Vireo; *Vireo olivaceus*; Black-capped Chickadee; *Parus atricapillus*; Golden-crowned Kinglet; *Regulus satrapa*; Ruby-crowned Kinglet; *Regulus calendula*; Tennessee Warbler; *Oreothlypis peregrina*; Orange-crowned Warbler; *Oreothlypis celata*; Nashville Warbler; *Oreothlypis ruficapilla*; Common Yellowthroat; *Geothlypis trichas*; Magnolia Warbler; *Setophaga magnolia*; Yellow-rumped Warbler; *Setophaga coronata*; American Goldfinch; *Spinus tristis*; entanglement; accidental mortality; foraging; migration; alien plants; Manitoba

Birds are victims of several types of accidental mortality (Erickson et al. 2005). One of the more unusual causes of death is entanglement in plants (Hager et al. 2009). The types of entanglements involved and plants include becoming stuck within or speared on the branches of trees or shrubs (Lloyd 1923; Sherick 1966), entwined by the blades of sedges (Bond 1960), impaled by thorns or cactus spines (Delareuelee 1973; Shackelford and Shackelford 2001), caught in the inflorescences or seed heads of grasses (Powers et al. 1981; Rodríguez et al. 2009), and tangled in the burrs of herbaceous plants (Craves 1998; Underwood and Underwood 2013).

In North America, the most numerous entanglements reported in plants are of birds in burdocks (*Arctium* spp.), invasive plants native to Eurasia (McNicholl 1988, 1994; Catling 2006; Hager et al. 2009). The large hooked burrs of burdock plants are very effective at epizoochory, i.e., adhering to the external surface of animals for seed dispersal (Kulbaba et al. 2009), but they also trap small birds and other animals (McNicholl 1988).

Across North America, more than 90 birds of at least 15 species have been found entangled in burdock burrs (McNicholl 1994; Hinam et al. 2004; Catling 2006).

Most of these records represent anecdotal reports of one or a few birds found entangled in a single area. In a noteworthy exception, Hinam et al. (2004) summarized 16 birds found entangled and reported a preponderance of migrants among all birds found entangled and a preponderance of juveniles among Ruby-throated Hummingbirds (*Archilochus colubris*) found entangled. The lack of other studies with large samples of birds found entangled has limited the availability of descriptive data from which to identify the attributes of birds that may increase the risk of entanglement.

Relatively little is known about risk factors for entanglement, especially what makes burdocks attractive to birds and leads to their becoming entangled. Several authors have speculated on the potential sources of attraction of burdock plants or the reasons for birds becoming entangled in burrs. These include seeking nectar from flowers (McAlpine 1976; Hinam et al. 2004), probing burrs for seeds (Bowdish 1906; Terres 1980) or insects (Needham 1909), perching on burrs (Stegeman 1953; Nealen and Nealen 2000), and a combination of perching and foraging on burdock plants (Stensaas 1989; Underwood and Underwood 2001). Alternatively, other events or activities may force birds to come into accidental contact with burrs, such as gusts of wind

(Herzberg and Juhola 1986; McNicholl 1988), aggressive interactions between conspecifics (Hinam et al. 2004), or chasing insect prey (Hager et al. 2009). However, there has been no direct study of the sources of attraction to burdocks and the reasons for entanglement.

In this five-year study, we searched natural areas in Winnipeg, Manitoba, for birds entangled in burdocks, and we recorded detailed behavioural observations of bird activity on burdock plants. Our first objective was to analyze trends by taxon, sex, age, migratory status, and time of year among the large number of birds found entangled in order to identify patterns that may influence the probability of entanglement. Our second objective was to compare records of birds found entangled to observations of bird activity on burdocks to identify behaviours that influence the risk of entanglement, to identify the potential attraction to burdock plants, and to examine the risk of entanglement by body mass.

Methods

Data collection

From September 2000 through May 2005, we opportunistically searched natural areas for birds entangled in burdocks in the southern part of the city of Winnipeg, Manitoba (49°48'N, 97°8'W). We visited these areas to conduct bird and natural history observations as our schedules and the weather allowed. A typical visit lasted approximately one hour and consisted of walking a loop through the area while observing live birds and scanning burdock patches we passed for entangled birds or bird activity. Over five years, we averaged 73.6 (SD 30.9, $n = 368$) visits per year to natural areas. In addition, one entangled bird was brought to us by a colleague.

Natural areas searched included King's Park (37 ha), La Barriere Park (84 ha), Maple Grove Park (62 ha), and the agricultural research area on the Fort Garry Campus of the University of Manitoba (43 ha). Most areas are along the Red River, except La Barriere Park, which is along the La Salle River, a tributary of the Red River. The riparian forest habitat of these areas had some trails through the forest and open mowed lawn. Burdocks were abundant in each area, with many large patches (e.g., $\geq 3 \times 3$ m) as well as isolated individual plants present along edges, trails, and openings in woodlands.

We believe that most of the burdock plants in these areas were Great Burdock (*Arctium lappa*) and Woolly Burdock (*A. tomentosum*), based on the large height of the plants (1–3 m), the length of the peduncles, and the wide diameter (> 2 cm) of the burrs (Scoggan 1957). We did not identify the species of burdock plant in which each bird was found entangled because of the difficulty in distinguishing the species without fresh flowers. Because of this challenge, we incorrectly identified these plants as Common Burdock (*A. minus*) in a previous paper (Underwood and Underwood 2001).

For each entangled bird found dead, we described its condition and deposited the specimen in the Manitoba Museum, Winnipeg, Manitoba (MM) (acronyms follow the Registry of Biological Repositories, <http://www.bio-repositories.org>), or the University of Manitoba Zoology Museum (UMBZM), also in Winnipeg. The University of Manitoba Zoology Museum held appropriate salvage permits (Appendix 1). Freshly killed birds had their plumage in good condition, eyes still intact, and no odour of decay. Birds beginning to decompose had one or more of the following: exposed flesh, desiccated or sunken eyes, and an odour of decay. Birds that were mostly decomposed consisted of mainly feathers and bones.

We identified each bird by species, sex, and age using plumage characters and measurements (Pyle 1997). We attempted to release entangled birds found alive, and we recorded the species, sex, and age where possible. One bird that died after extraction from the burrs was sexed by dissection and prepared as a museum skin (UMBZM 902) (Appendix 1).

We also recorded observations of bird activity that involved contact with burdock plants to assess behaviours that may influence the risk of entanglement. Because bird activity on burdocks was infrequent and unpredictable, we used *ad libitum* sampling to document all behaviours of individuals in our notebooks over the period birds were visible (typically a few seconds to a few minutes). This method of behavioural sampling is appropriate for rare and unpredictable events (Dawkins 2007). From our detailed field notes, we categorized behaviours by species and whether birds were observed perching or foraging on particular parts of burdock plants.

Analyses

We summarized records of birds found entangled by taxon, sex, age, migratory status, and season. Data from the fall of 2000, previously described but not analyzed (Underwood and Underwood 2001), were also included. We compared the birds' sex, age, and migratory status using χ^2 tests; when expected values were below five, we used Fisher's exact tests. To analyze the timing of entanglements, we categorized timing by season as defined by the Checklist of the Birds of Manitoba (Manitoba Avian Research Committee 2009): spring (March–May), summer (June–August), fall (September–November), and winter (December–February).

Because our search effort varied by season (proportion of visits/season = 34.2% in spring, 23.4% in summer, 30.2% in fall, 12.2% in winter; $n = 368$), we standardized seasonal data by the average number of birds found entangled per visit. Only birds we found alive, freshly dead, or just beginning to decompose ($n = 18$ birds) were included because they were likely to have been caught within three weeks of discovery and could be confidently assigned to a season. The bird brought to us by a colleague was excluded from this analysis. Because these data were not normally distributed, we



FIGURE 1. Birds found entangled in burdock (*Arctium* spp.) burrs in Winnipeg, Manitoba: Ruby-crowned Kinglet (*Regulus calendula*) (left) found alive on 21 September 2001 and Yellow-bellied Flycatcher (*Empidonax flaviventris*) found dead on 13 September 2001.

used a Kruskal-Wallis test to analyze the timing of entanglements.

We visually compared the frequency of entanglements to that of bird activity on burdock by family. We compared the number of species that were found entangled to the number not found entangled by their type of activity on burdocks. A Fisher’s exact test was used for this analysis because expected values were below five. We compared the body mass of species found entangled to the body mass of species not found entangled but recorded as being active on burdocks. Because these data were not normally distributed, we used a Mann-Whitney *U* test. The average mass of each species was obtained from the Birds of North America species accounts.

Results

We discovered 28 birds entangled in burdocks, for an average of 0.08 birds found/visit (SE 0.02, *n* = 368 visits) to a natural area. Overall, we documented a total of 29 birds from 13 species entangled in burdocks (Figure 1, Table 1). The birds most commonly found entangled were New World warblers (Parulidae), but small numbers of species in five other families were also found (Table 1, Figure 2). Only two of these birds were found alive: a Ruby-crowned Kinglet (see Table 1 for scientific names of birds) (Figure 1) was extracted and flew away upon release and a fledgling Least Flycatcher that was in poor condition died after we brought it to a wildlife rehabilitation centre. We also

TABLE 1. The number of birds found entangled in burdocks (*Arctium* spp.) in Winnipeg, Manitoba, from 2000 to 2005, by species, with their migratory status and average body mass.

Species and family	No. of birds found entangled	Migratory status ¹	Body mass (g)and source ²
Yellow-bellied Flycatcher (<i>flaviventris</i>) (Tyrannidae)	1	migrant	11.3 (Gross and Lowther 2011)
Least Flycatcher (<i>Empidonax minimus</i>) (Tyrannidae)	3	breeder	10.5 (Tarof and Briskie 2008)
Blue-headed Vireo (<i>Vireo solitarius</i>) (Vireonidae)	1	migrant	15.4 (James 1998)
Red-eyed Vireo (<i>Vireo olivaceus</i>) (Vireonidae)	1	breeder	20.3 (Cimprich et al. 2000)
Black-capped Chickadee (<i>Poecile atricapillus</i>) (Paridae)	1	breeder	12.2 (Foote et al. 2010)
Golden-crowned Kinglet (<i>Regulus satrapa</i>) (Parulidae)	1	migrant	6.2 (Swanson et al. 2012)
Ruby-crowned Kinglet (<i>Regulus calendula</i>) (Parulidae)	2	migrant	6.7 (Swanson et al. 2008)
Tennessee Warbler (<i>Oreothlypis peregrina</i>) (Parulidae)	7	migrant	9.6 (Rimmer and McFarland 1998)
Orange-crowned Warbler (<i>Oreothlypis celata</i>) (Parulidae)	3	migrant	9.4 (Gilbert et al. 2010)
Nashville Warbler (<i>Oreothlypis ruficapilla</i>) (Parulidae)	5	migrant	8.8 (Lowther and Williams 2011)
Magnolia Warbler (<i>Setophaga magnolia</i>) (Parulidae)	2	migrant	8.5 (Dunn and Hall 2010)
Yellow-rumped Warbler (<i>Setophaga coronata</i>) (Parulidae)	1	migrant	12.6 (Hunt and Flaspohler 1998)
American Goldfinch (<i>Spinus tristis</i>) (Fringillidae)	1	breeder	11.4 (McGraw and Middleton 2009)
Total no. of birds found entangled	29		

¹Migratory or breeding status of birds in natural areas where found entangled (Taylor et al. 2003; TJU and RMU, personal observations).
²Represents the mass of both sexes or, when reported separately by sex, the average mass of both sexes.

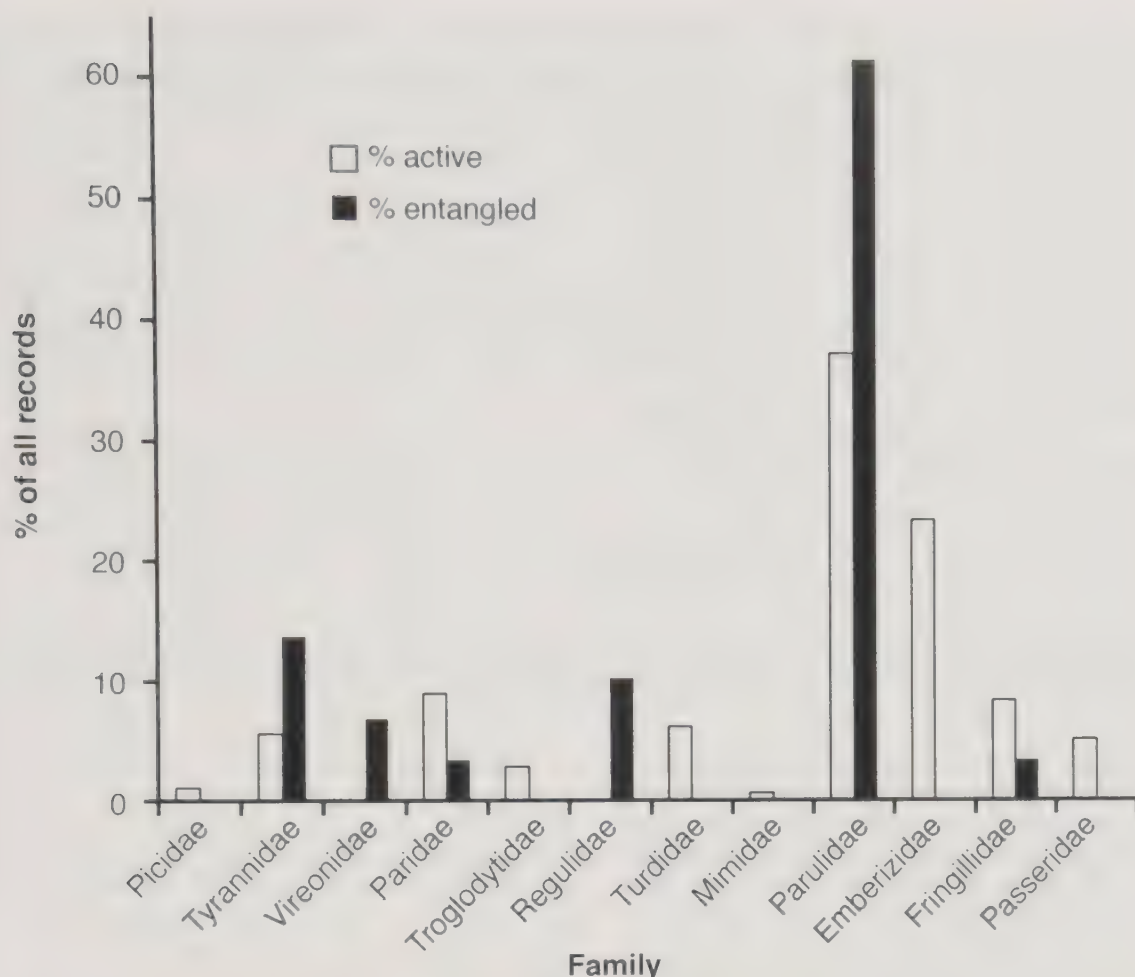


FIGURE 2. A comparison of the relative frequency of birds found entangled in burdocks (*Arctium* spp.) ($n = 29$) with birds observed active on burdocks ($n = 178$), by family, in Winnipeg, Manitoba, from 2000 to 2005.

found a few feathers from unknown species attached to burrs on three separate dates (Appendix 1). The colour patterns on two sets of feathers suggest they were possibly from sparrows, whereas the third set of feathers could have been from any one of several potential species (Appendix 1).

Most specimens (18) could not be sexed and 6 could not be aged due to their condition. The distribution of birds found entangled that could be sexed (3 males and 8 females) (Appendix 1) did not differ significantly by sex ($\chi^2 = 2.27$, $P = 0.13$), and the distribution of birds found entangled whose age could be determined (12 after-hatch year and 11 hatch year) (Appendix 1) did not differ by age ($\chi^2 = 0.04$, $P = 0.84$). Migrants were found entangled significantly more often than birds known to breed in the area (23 migrants and 6 breeders) (Table 1) ($\chi^2 = 9.97$, $P < 0.01$). The average number of birds found entangled per visit differed significantly by season ($H = 12.25$, $df = 3$, $P < 0.01$) ($x = 0.02$ visit, $SE = 0.01$, $n = 126$ visits in spring; $x = 0.02$ visit, $SE = 0.02$, $n = 86$ visits in summer; $x = 0.13$ visit, $SE = 0.05$, $n = 111$ visits in fall; $x = 0.00$ visit, $n = 45$ visits

in winter). Entangled birds were discovered most frequently during fall (14 of 18 birds we found entangled that were assigned to a season) (Appendix 1).

We recorded 34 species of birds active on burdocks ($n = 178$ observations). Warblers and sparrows (Emberizidae) were the most frequent groups of birds recorded as being active on burdocks, followed by small numbers of birds from eight other families (Figure 2). Other than warblers, the frequency of activity on burdocks poorly matched the frequency of birds found entangled at the family level (Figure 2). Despite being found entangled in burdocks, no birds in the families Vireonidae and Regulidae were recorded as being active on burdocks. Of all bird behaviours on burdocks, 79% involved perching and 21% involved foraging. Observations of perching only involved perching on burdock stems, never on actual burrs.

We found that species that actively foraged on burdocks were found entangled significantly more often than species that only perched on burdocks (Fisher's exact test, $P < 0.01$) (Figure 3). Birds recorded foraging on burdocks ($n = 37$ observations) were most often war-

TABLE 2. The number of observations of birds recorded foraging on burdocks (*Arctium* spp.), by foraging behaviour, in Winnipeg, Manitoba, from 2000 to 2005.

Foraging behaviour	Species	No. of observations
Probing dead leaves	Black-capped Chickadee	5
	Tennessee Warbler	1
	Orange-crowned Warbler	5
	Nashville Warbler	3
	Common Yellowthroat	1
	Subtotal	15
Probing burrs	Black-capped Chickadee	3
	Orange-crowned Warbler	1
	Yellow-rumped Warbler	3
	Subtotal	7
Pecking at stem	Downy Woodpecker	2
	Subtotal	2
Probing burr and green leaves	Black-capped Chickadee	1
	Subtotal	1
General ¹	Tennessee Warbler	1
	Orange-crowned Warbler	6
	Yellow-rumped Warbler	5
Subtotal		12
Total		37

¹No specific foraging location or activity was noted for these observations.

blers (70.3%), but also included chickadees (Paridae) (24.3%) and woodpeckers (Picidae) (5.4%) (Table 2). Of the specific foraging behaviours noted ($n = 25$), probing dead leaves (60%) was the most commonly recorded (Table 2). We also found that species that were active on burdocks, but were not found entangled, had significantly greater body mass than species found entangled ($U = 57.5$, $P < 0.01$; $\bar{x} = 23.3$ g, SE 2.9, $n = 26$ vs. $\bar{x} = 11.0$ g, SE 1.0, $n = 13$).

Discussion

We found 13 species of birds entangled in burdocks. Of these birds, 3 species—Yellow-bellied Flycatcher, Red-eyed Vireo, and Orange-crowned Warbler—have not been previously recorded entangled in burdocks (McNicholl 1994; Catling 2006; Hager et al. 2009). The 29 birds we found in the same general area across five years represent one of the largest sets of burdock entanglements from a single area.

Only a few published reports have identified large numbers of birds found entangled. Needham (1909) reported “scores” of Golden-crowned Kinglets entangled in burdocks in Illinois on a single day, but did not provide an actual count of these birds. However, scores, i.e., multiples of 20, implies at least 40 birds. More recently, Iron (2002) discovered 11 kinglets, mostly Golden-crowned Kinglets, in one year in a single park in Ontario, and Hinam et al. (2004) summarized 16 birds, mostly Ruby-throated Hummingbirds, over 21 years in Delta Marsh, Manitoba.

We suspect that the large number of birds found entangled in this study was a consequence of the abundance of burdocks in the areas we searched and the importance of these areas for migration. Most of the birds

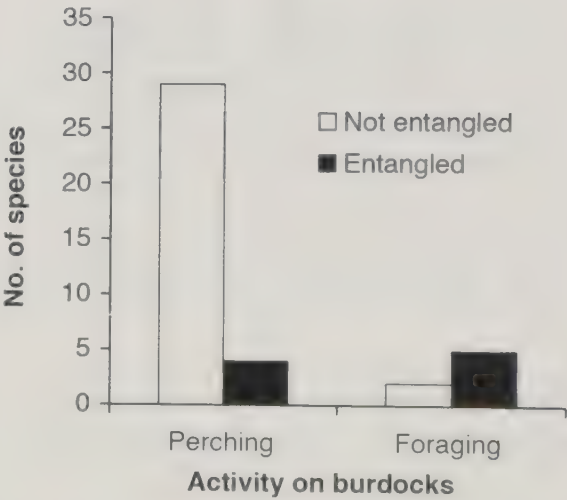


FIGURE 3. A comparison of the number of species found entangled in burdocks (*Arctium* spp.) with the number of species not recorded entangled in burdocks, by the type of activity recorded on burdocks in Winnipeg, Manitoba, from 2000 to 2005.

found entangled were among large patches ($\geq 3 \times 3$ m) of burdocks rather than in isolated plants. The Red River valley is an important north south migration corridor for raptors, waterfowl, and songbirds (Taylor et al. 2003). The riparian habitat along the river constitutes important stopover habitat for migratory birds amongst the farmland and urban suburban areas that surround the Red River in southern Manitoba. For example, in King’s Park, we documented over 150 species of birds, mostly migrants, utilizing the park (2000–2005, TJU and RMU, personal observations). Bird en-

entanglements at Delta Marsh, Manitoba, have been similarly linked to the importance of riparian habitat to migratory birds (Hinam et al. 2004).

There was no difference in the numbers of birds found entangled by sex. The lack of a sex difference is not unexpected, because there is no strong basis to suggest a sex-biased risk of entanglement, unless aggressive interactions between males strongly influence entanglement (e.g., Hinam et al. 2004). For example, there is no overall sex bias in the number of birds killed through other types of accidental mortality, such as collisions with towers or windows (Crawford 1978; Klem 1989).

Although we found no significant difference by age, this result may be an artifact of sample size. Age is more likely to be important because lack of experience may increase a bird's risk of becoming entangled in burdocks (Kubisz 1989). Furthermore, young birds may be more susceptible to accidents because there are more of them in the population in the fall (Klem 1989; Crawford and Engstrom 2001). The two other studies with a large number of one species reported being entangled in burdocks found more juveniles than adults among Golden-crowned Kinglets (Needham 1909) and Ruby-throated Hummingbirds (Hinam et al. 2004). The small sample sizes of each species necessitated that these data be pooled for analysis, and we suspect that this may have influenced the lack of significant differences in our data.

Most birds found entangled in this study were migrant songbirds that were captured during fall. Breeding birds made up only a small portion of entanglements, and few birds found entangled were discovered in summer or winter. A similar trend for migrants was noted at Delta Marsh, Manitoba (Hinam et al. 2004). Migrants comprise a large portion of birds killed through accidental collisions with towers (Crawford and Engstrom 2001) and windows (Klem 1989), although collisions with windows are also responsible for the deaths of many winter residents attracted by bird feeders (Klem 2010). A similar larger number of birds killed at towers during fall migration has been suggested to be due in part to more birds migrating at this time (i.e., offspring from the breeding season and before any migration or winter mortality) (Crawford and Engstrom 2001).

The higher average of entangled birds discovered in fall than in spring was likely due to this discrepancy in the size of the migrating population but also due to burdock phenology. In southern Manitoba, burdock plants flower from mid-July into September (Kenkel and Graham 1994) and die thereafter. The fresh green flowers or burrs are just as adherent as dried burrs (TJU, personal observation) and can entrap birds (e.g., Hinam et al. 2004). By late summer, when fall migration begins, a fresh crop of burrs is available, but over the winter many of these burrs fall off, e.g., >60% of *Arctium lappa* burrs and >20% of *A. minus* burrs (Hawthorn and

Hayne 1978), or entire plants may be knocked down. Thus, the environmental risk of entanglement peaks in late summer and fall when songbirds are migrating through southern Manitoba. Migrants may also be at a higher risk of entrapment because they may be less familiar with the surroundings than resident birds.

The frequency of bird activity on burdocks closely matched records of entanglement only for warblers and was a poor match for most other families, especially sparrows (Figure 2). This discrepancy is likely explained by the type of activities observed on burdock plants. Species that only perched on burdocks were found entangled less often than species that foraged on burdocks. We recorded high sparrow activity on burdocks, but all of the sparrows we observed on burdocks were perching. Sparrows typically forage on the ground and use perches above ground to sing or to pause after being flushed from the ground (Rising 1996). Thus, simple perching on burdock stems does not appear to be a risky behaviour, perhaps because it is only momentary and birds do not come into contact with burrs.

By comparison, Downy Woodpeckers (*Picoides pubescens*) and Common Yellowthroats (*Geothlypis trichas*) were the only two of seven species that we recorded foraging on burdocks that were never found entangled. The Downy Woodpecker is large-bodied (28 g) (Jackson and Ouellet 2002), and it was observed only perched on and pecking at the main flowering stalk of burdocks, a behaviour that may present a risk more similar to perching than foraging. Most observations of foraging involved birds moving among a patch of plants and stopping to probe inside dead leaves or to probe inside burrs. Thus, these movements among the burdock plants and deliberate contact with burrs appear to strongly increase a bird's risk of becoming entangled.

We suspect that the tendency of songbirds to forage among burdock plants is influenced by weather. A large number of entangled birds (12) was discovered between 19 September and 4 October 2003 (Appendix 1), during a period of cooler-than-average weather. This period in 2003 had the coldest average daily temperature (6.6°C) in Winnipeg compared to the same period in any of the ten years surrounding this study (1996–2005, overall \bar{x} = 9.5°C, SE 0.38, n = 10) (Environment Canada 2013*). Weather has a strong impact on foraging behaviour in some birds. For example, resident woodland songbirds, such as Black-capped Chickadees and Tufted Titmice (*Baeolophus bicolor*), respond to lower temperatures and higher wind speeds in winter by reducing their foraging height from the canopy to the shrub layer and altering their foraging substrate (Grubb 1975). Furthermore, unseasonably cool or inclement weather during migration in Manitoba has been linked to changes in the foraging behaviour of insectivorous warblers, which switch from feeding in the canopy to feeding on or near the ground (Sealy 1988, 1989). Inclement weather during migration could

force birds that typically forage in the canopy of the forest, such as warblers and vireos, to move into the shrub layer, where burdocks were abundant in certain locations in the study areas.

Most birds in the study areas appear to be attracted to burdock plants by arthropod prey. Birds found entangled were mostly insectivores (i.e., flycatchers, vireos, kinglets, and warblers), although some also eat fruit during migration (Hunt and Flaspohler 1998; James 1998; Rimmer and McFarland 1998; Cimprich et al. 2000; Swanson et al. 2008; Tarof and Briskie 2008; Dunn and Hall 2010; Gilbert et al. 2010; Gross and Lowther 2011; Lowther and Williams 2011; Swanson et al. 2012). Only two of the bird species we found entangled, Black-capped Chickadee and American Goldfinch, regularly eat seeds (Martin et al. 1961) and might be attracted to burrs for their seeds.

Burdock plants provide habitat for arthropod prey in their dead dried leaves and their burrs. In both temperate and tropical forests, dried leaves contain a larger number and higher biomass of arthropods than live green leaves (Greenberg 1987). Foraging in dead leaves is a specialized niche used mainly during the non-breeding season by several Neotropical resident and migrant songbirds (Remsen and Parker 1984; Greenberg 1987; Remsen et al. 1989). Four species of Neotropical migrant warblers in the former genus *Vermivora*, including Orange-crowned Warblers, have been reported to specialize in this foraging behaviour in winter. Some temperate residents may also regularly forage in dead leaves (Remsen et al. 1989).

We observed four different species of warblers and Black-capped Chickadees probing dead leaves (Table 2), but rarely observed them capturing prey because we were not close enough to the birds. On 16 September 2001, we observed an Orange-crowned Warbler capture a caterpillar from within a dead burdock leaf. Although arthropod abundance in dead burdock leaves has not been quantified, our observations suggest that prey are available and birds are attracted to burdocks to forage for arthropods.

Burdock burrs also house potential arthropod prey for birds. Moths, bees, grasshoppers, and other insects occasionally become stuck to burrs (Zimmer and Kantrud 1987; McHveen and Gaunt 2009; TJU, personal observation) and might be prey for birds when they are still fresh. A more important and regular source of prey is the larvae of the Burdock Seedhead Moth (*Metzneria lappella*). These larvae are seed predators that feed on developing burdock seeds inside the burrs (Gross et al. 1980). *Metzneria lappella* larvae may be quite abundant and have been found to occupy 34% of *Arctium lappa* burrs, with an average of 0.6 larvae per burr, and *M. lappella* larvae have been found to occupy 80–99% of *A. minus* burrs, with an average of 1.4 to 4.0 larvae per burr (Hawthorn and Hayne 1978).

Needham (1909) was the first to point out that *M. lappella* larvae likely attract birds to the burrs. His suggestion has often been repeated in the literature but without any confirmation that birds are capturing insect larvae from burrs. On 3 September 2003, we observed a Yellow-rumped Warbler take a small insect larva, possibly *M. lappella*, from a burr, providing the first real evidence that birds are attracted to burrs to forage on insects. First-instar *M. lappella* larvae appear in burrs by late July, mature in fall, and overwinter as larvae in burrs (Hawthorn and Hayne 1978). Thus, the availability of insects on burrs remains high during fall, providing another link to the greater number of birds found entangled in the fall.

The presence of arthropod prey on burdock leaves and in burrs might not be considered an attractant for *Empidonax* flycatchers because of their use of hawking manoeuvres to capture aerial prey. However, *Empidonax* flycatchers, especially Least Flycatchers, regularly glean insects from vegetation (Murphy 1989). Least Flycatchers are also known to forage lower in the canopy and to glean prey from vegetation more often during inclement weather (Tarof and Briskie 2008). These foraging behaviours suggest that *Empidonax* flycatchers might be apt to forage for arthropod prey on burdock plants, particularly during inclement weather. Alternatively, flycatchers might come into contact with burdock burrs accidentally while actively pursuing aerial insects (Hager et al. 2009) or if they use burdocks as a perch from which to hawk insects.

In addition to bird activity on burdocks, body mass likely influences the probability of becoming entangled. Species of birds active on burdocks, but never found entangled, had a greater body mass than species found entangled. The species found entangled in our study ranged from 6 to 20 g in body mass, and all but two species (Blue-headed Vireo and Red-eyed Vireo) weighed less than 13 g (Table 1). Unfortunately, our specimens of only feathers stuck to burrs did not have any colours or patterns distinct enough to allow a positive identification to be made.

The presence of a few body feathers suggests that some birds are occasionally able to escape becoming fatally entangled. Alternatively, feathers found on burrs may suggest these birds were taken by scavengers, as is known to occur with the carcasses from other types of accidental mortality (Longcore et al. 2012). However, based on the extent to which most birds were entangled in burrs (Figure 1) (see Underwood and Underwood 2001), we would expect more body parts or blood to be left behind if birds were scavenged.

The identity of species capable of extracting themselves from burrs might help identify the size limits of birds at risk of becoming entangled. Other reports of birds found entangled in burdocks (summarized in McNicholl 1994; Catling 2006; Hager et al. 2009) re-

flect a size range of small birds—Ruby-throated Hummingbirds to Blue-headed Vireos—similar to the birds in this study. These results suggest that birds larger than 20 g are less likely to become entangled in burdocks than smaller birds.

We found a relatively large number of birds entangled in burdocks over five years in natural areas in Winnipeg, Manitoba. The overall number of birds that were found entangled suggests that entanglement in burdocks may not be as rare as indicated by previous anecdotal reports. However, the relatively low number of birds found entangled per visit also suggests that burdocks may not constitute a major source of mortality on a regional scale, compared to accidental collisions with anthropogenic structures (e.g., Erickson et al. 2005).

The concentration of birds found entangled in areas searched was likely due to the abundance of burdock plants and the importance of these riparian areas as stopover habitat to songbird migrants. Thus, burdock mortality may be important only in certain local areas. Birds found entangled were mostly insectivorous migrants that had become entangled during fall, but there were no trends by age or sex.

Our observations showed that birds are attracted to burdock plants by arthropod prey among dead leaves and burrs. Foraging activity on burdocks combined with small body size appears to greatly increase a bird's risk of fatal entanglement, whereas perching is a less risky activity. We suggest that inclement weather may influence entanglements by forcing insectivores out of the canopy to forage closer to the ground and amongst burdock plants. Future studies are needed to understand the importance of burdock-related bird mortality on a broader geographic scale and to examine how foraging behaviour around burdocks relates to weather conditions.

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APPENDIX 1. Records of birds found entangled in burdocks (*Jeritum* spp.) in Winnipeg, Manitoba, from 2000 to 2005, with descriptive data.

Species	Sex	Age ¹	Condition	Date found	Season ²	Specimen no. and reference
Yellow-bellied Flycatcher	Unknown	HY ³	Dead (fresh)	13 September 2001	Fall	UMBZM 903
Least Flycatcher	Unknown	HY ³	Dead (beginning to decompose)	4 November 2000	Fall	MM 1-2-4993 (Underwood and Underwood 2001)
Least Flycatcher	Female	HY ³	Alive; died later	17 August 2001	Summer	UMBZM 902
Least Flycatcher	Unknown	HY ³	Dead (beginning to decompose)	9 October 2001	Fall	UMBZM 3118
Blue-headed Vireo	Unknown	AHY ⁴	Dead (fresh)	26 September 2003	Fall	UMBZM 3123
Red-eyed Vireo	Unknown	AHY ⁴	Dead (mostly decomposed)	9 September 2001	Unknown	UMBZM 3117
Black-capped Chickadee	Unknown	HY ³	Dead (fresh)	31 August 2003	Summer	UMBZM 3119
Golden-crowned Kinglet	Female	AHY ⁴	Dead (fresh)	10 April 2005	Spring	UMBZM 3134
Ruby-crowned Kinglet	Female	Unknown	Alive; released	16 September 2001	Fall	
Ruby-crowned Kinglet	Male	AHY ⁴	Dead (fresh)	9 May 2004	Spring	UMBZM 3133
Tennessee Warbler	Unknown	Unknown	Dead (mostly decomposed)	26 November 2000	Unknown	MM 1-2-4992 (Underwood and Underwood 2001)
Tennessee Warbler	Unknown	HY ³	Dead (fresh)	13 September 2001	Fall	UMBZM 3116 (L. Hutchison, collector)
Tennessee Warbler	Male	AHY ⁴	Dead (beginning to decompose)	21 September 2003	Fall	UMBZM 3121
Tennessee Warbler	Unknown	AHY ⁴	Dead (fresh)	26 September 2003	Fall	UMBZM 3124
Tennessee Warbler	Unknown	HY ³	Dead (mostly decomposed)	3 October 2003	Unknown	UMBZM 3130
Tennessee Warbler	Unknown	HY ³	Dead (beginning to decompose)	4 October 2003	Fall	UMBZM 3131
Tennessee Warbler	Unknown	Unknown	Dead (mostly decomposed)	6 November 2004	Unknown	UMBZM 3135
Orange-crowned Warbler	Female	Unknown	Dead (beginning to decompose)	26 September 2003	Fall	UMBZM 3125
Orange-crowned Warbler	Female	AHY ⁴	Dead (beginning to decompose)	26 September 2003	Fall	UMBZM 3126
Orange-crowned Warbler	Male	HY ³	Dead (fresh)	27 September 2003	Fall	UMBZM 3128
Nashville Warbler	Female	AHY ⁴	Dead (beginning to decompose)	4 November 2000	Fall	MM 1-2-4995 (Underwood and Underwood 2001)
Nashville Warbler	Unknown	AHY ⁴	Dead (mostly decomposed)	4 November 2000	Unknown	MM 1-2-4990 (Underwood and Underwood 2001)
Nashville Warbler	Female	HY ³	Dead (beginning to decompose)	5 November 2000	Fall	MM 1-2-4994 (Underwood and Underwood 2001)
Nashville Warbler	Unknown	AHY ⁴	Dead (mostly decomposed)	11 November 2000	Unknown	MM 1-2-4989 (Underwood and Underwood 2001)
Nashville Warbler	Unknown	Unknown	Dead (mostly decomposed)	19 September 2003	Unknown	UMBZM 3120
Magnolia Warbler	Unknown	AHY ⁴	Dead (mostly decomposed)	26 September 2003	Unknown	UMBZM 3127
Magnolia Warbler	Unknown	Unknown	Dead (mostly decomposed)	27 September 2003	Unknown	UMBZM 3129
Yellow-rumped Warbler	Female	AHY ⁴	Dead (fresh)	3 October 2003	Fall	UMBZM 3132
American Goldfinch	Unknown	HY ³	Dead (mostly decomposed)	21 September 2003	Unknown	UMBZM 3122
Feathers ¹	Unknown	Unknown	Escaped?	26 September 2002	Unknown	UMBZM 3137
Feathers ⁴	Unknown	Unknown	Escaped?	6 September 2003	Unknown	UMBZM 3136
Feathers ⁵	Unknown	Unknown	Escaped?	12 September 2004	Unknown	UMBZM 3138

¹HY = hatch year; AHY = after hatch year

²Seasons (spring March May; summer June August; fall September November; winter December February) were based on the Checklist of the Birds of Manitoba (Manitoba Avian Research Committee 2009).

³Three contour feathers that have grey bases with light reddish-brown tips; possibly from a sparrow.

⁴Two contour feathers that have grey bases with light brown tips; possibly from a sparrow.

⁵Two contour feathers on one burr and seven contour feathers on three nearby burrs. Feathers have dark grey bases with white tips.

Notes

The Flight of a Flock of Common Eiders, *Somateria mollissima*, in Northumberland Strait Interrupted by the Confederation Bridge, New Brunswick–Prince Edward Island

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MacKinnon, Colin M., Andrew C. Kennedy, and Matthew L. Horsman. 2013. Flight of a flock of Common Eiders, *Somateria mollissima*, in Northumberland Strait interrupted by the Confederation Bridge, New Brunswick–Prince Edward Island. *Canadian Field-Naturalist* 127(2): 175–177.

An observation of the flight of a flock of Common Eiders, *Somateria mollissima*, on 24 October 2012 suggests that, 15 years after construction of the Confederation Bridge connecting New Brunswick and Prince Edward Island (12.9 km in length over the Northumberland Strait), the bridge may still be a partial barrier to bird flight and possibly migration. Although we believe the Common Eiders we observed intended to fly over or under the bridge, none of the 44 Common Eiders crossed the structure during the observation period.

Key Words: Common Eider; *Somateria mollissima*; Black Scoter; *Melanitta americana*; seaducks; migration; Confederation Bridge; Northumberland Strait; Cape Jourimain National Wildlife Area; New Brunswick; Prince Edward Island

Construction of the Confederation Bridge was completed in 1997, and it has been in operation for 15 years. The 12.9 km long structure spans the Northumberland Strait at its narrowest point, between Cape Jourimain National Wildlife Area, New Brunswick, and Borden, Prince Edward Island (Figure 1). The Confederation Bridge utilizes a multi-span concrete box girder structure and is composed of three main components: the approaches (east and west), a deck 40 m high, and a ship navigation span 60 m high. The east approach is 0.6 km over 7 piers and the west approach is 1.3 km over 14 piers. The main bridge is 11.0 km (44 piers) in length, with the elevated navigation section 2.50 km in length in the middle. The typical span between piers is 250 m.

As part of collecting pre-construction baseline data in 1990 and as part of the environmental assessment process for the proposed bridge, MacKinnon et al. (1991) monitored seabird and seaduck movement through the Northumberland Strait. Twenty-two hours of surveys, during spring and fall, produced 5214 observations of 25 species. Of these, 641 (12.3%) were Common Eiders, *Somateria mollissima* (MacKinnon et al. 1991).

During the early 1990s, concerns were expressed about the possible effects that the Confederation Bridge might have on seabird migration; such as being a barrier to flight. The closest comparable structure at that time was the Canso Causeway, which connects Cape Breton Island with mainland Nova Scotia. Erskine and Smith (1986) reported that, although the causeway was a comparatively low and short structure, it was believed to be a barrier to flight for Common Eiders.

In 1997, Hicklin and Bunker-Popma (2001) conducted surveys at the Confederation Bridge during the spring migration, similar to those reported by Mac-



FIGURE 1. Orientation of the Confederation Bridge, connecting New Brunswick with Prince Edward Island, and the route of the Common Eider, *Somateria mollissima*, flock observed on 24 October 2012.

Kinnon et al. (1991). The Confederation Bridge was then in operation, and comparison with observations of MacKinnon et al. (1991) suggested that it formed a partial barrier to scoter (*Melanitta* spp.) migration. MacKinnon and Kennedy (2006) reported such an occurrence. On 13 April 2006, a flock of 18 Black Scoters, *Melanitta americana* (formerly *M. nigra*), repeatedly tried to cross over the bridge with only partial success; only 3 birds (17%) crossed over during the observation period.

No comparable observations have been reported concerning Common Eiders. It is recognized, however, that Common Eiders generally avoid flying over land (Gauthier et al. 1976) and, when they do, have been known

to collide with anthropogenic structures (MacKinnon and Kennedy 2011). It is also important to note that recent studies of flight altitudes of some species of migrating seaducks show that, under certain conditions, seaducks may fly high enough to avoid some anthropogenic obstacles (Kahlert et al. 2012).

At noon (1200) on 24 October 2012, we observed a flock of Common Eiders as we were travelling across the Confederation Bridge from Prince Edward Island to New Brunswick by vehicle ($46^{\circ}12'N$, $63^{\circ}45'W$). At the time of the observation, visibility was excellent with 95% high cloud cover, temperature of $15^{\circ}C$, and light winds from the northwest.

Shortly after we entered the Confederation Bridge from Borden, Prince Edward Island, at 1150, we observed the flock of Common Eiders (divided into two groups of 25 and 19 birds separated by >100 m) approaching the bridge at an oblique angle from the north. The flock was possibly on its southward migration (this species does not breed in the Northumberland Strait and winters in only small numbers (Boyer 1972; Lock 1986; Erskine 1987; Goudie et al. 2000).

The birds were first sighted about 1 km west of the coastline of Prince Edward Island (Figure 1). As they approached the bridge, the two sets of birds turned to the southwest and proceeded to fly parallel with, and approximately 75–100 m north of, the Confederation Bridge at a height of <10 m above the water. The two groups of birds, now separated by <75 m, remained at a more or less constant speed, and we observed them continue on an essentially straight southwesterly direction parallel to the course of the bridge for approximately 10.6 km. Although some of the birds were occasionally lost from sight for brief periods (<25 seconds), at no time did the birds appear to attempt to fly over or underneath the bridge.

Once the birds had passed the elevated navigation channel situated in the middle of the Northumberland Strait, the two groups of birds merged (Figure 2). Near the New Brunswick coastline, at a point 1350 m from shore where the level deck of the bridge (40 m above the water) starts to slope down towards the bridge abutment, the speed of the flock decreased noticeably. At this point, the flock dispersed slightly. It started to gain



FIGURE 2. Flock of Common Eiders, *Somateria mollissima*, flying parallel to the Confederation Bridge (birds indicated by tick marks in inset) on 24 October 2012. Photograph location $46^{\circ}11'49.2''N$, $63^{\circ}46'15.8''W$, 5 km from the Cape Jourimain (New Brunswick) headland, located at the middle left of the photograph. The bridge deck is 40 m above the water. Photo: C. MacKinnon.

altitude but remained below the level of the bridge deck. The flock quickly regrouped, dropped altitude to the original <10 m above sea level, and changed course to a more northwesterly direction heading away from the bridge.

The flock was last seen at 1205 continuing over the water in a northward direction approximately 1 km east of the Cape Jourmain (New Brunswick) headland (Figure 1), having never crossed over or under the bridge.

The velocity of the vehicle in which we were driving during the observation period ranged from 62 to 80 km/hour, with an average rate of 75 km/hour. Throughout the crossing, the Common Eiders were either parallel to or just slightly ahead of the observers. Observations ceased at 1205. It is noteworthy that the Confederation Bridge is built in a gentle "S" curve; thus the flight of the Common Eider flock clearly followed the contours of the bridge and did not go in a straight line across the Northumberland Strait.

This observation demonstrates that 15 years after construction, the Confederation Bridge may be perceived by Common Eiders as a partial barrier to flight as well as possibly to their southward migration through the Northumberland Strait in the fall. More detailed observations are required to ascertain how significant a deterrent the bridge is to eider spring or fall migration. This note may also assist in decision making for other comparable mega-structures in the marine environment.

Concerns similar to those raised in the early 1990s about the Confederation Bridge are now being expressed regarding the possible impacts on seabird movement of a proposed bridge across the Suur Väin Strait in western Estonia, recognized as a significant waterbird migration route in northern Europe (Kahlert et al. 2012).

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Documentation of Infanticide in American Marten (*Martes americana*)

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Reports of male American Martens (*Martes americana*) interacting with pre-weaned kits are limited. During the post-release monitoring of American Martens translocated from Minnesota to northwestern Wisconsin in 2008–2010, we documented a male American Marten without a radio-collar ascending a den tree of a radio-collared female in 2011 and removing two pre-weaned kits. The female's movements immediately became unrestricted after the removal. We also documented two events where an uncollared male American Marten was at the den tree before and after the kit removal. Only female American Martens have been reported to provide care for kits. Visual inspection of the remote camera photographs suggests that all three events likely involved the same uncollared male American Marten. This is the first record of a male American Marten killing pre-weaned kits.

Key Words: *Martes Americana*; American Marten; kits; infanticide; den; Wisconsin

Accounts of American Martens (*Martes americana*) killing other American Martens in the wild are rare. To our knowledge, there are no accounts of American Martens killing pre-weaned kits (1–6 weeks old), but fatal interactions among juvenile and adult males have been reported (Bull and Heater 1995; Bull and Heater 2001). Intact carcasses and overlapping home range data suggest these events occur for territorial reasons (Bull and Heater 1995; Bull and Heater 2001). Jones et al. (1997) observed adult male American Martens at 6 of 16 (38%) maternal dens, with males scent marking, investigating, or stealing prey without causing harm to kits. Ruggiero and Henry (1993) observed dependent kits present during adult American Marten copulation events and even observed an adult male resting with a kit (15 weeks old) for approximately 4 hours.

Ninety American Martens (55 females) were captured in Minnesota and released in northwestern Wisconsin during a three-year translocation project from 2008 to 2010 (Woodford et al. 2013). For the post-release monitoring, 31 of the translocated animals were followed using radio-telemetry 1–3 times a week. The study area was centered on 46°17'N, 90°55'W and encompassed 1882 km² of the Chequamegon-Nicolet National Forest and surrounding areas (Woodford et al. 2013).

A radio-collared adult female (E35), released in the fall of 2010, started to restrict her movements and established a den in an Eastern White Cedar (*Thuja occidentalis*) between 15 and 21 April 2011. During this period, the locations of E35 were never >388 m from the den tree. This period coincides with the normal parturition period reported for American Martens (Henry and Ruggiero 1993*; Henry et al. 1997; Jones et al. 1997; Erb et al. 2010*).

E35 was radio-tracked to the den tree on 22 April 2011, and three infrared cameras (Reconyx PC900, Reconyx Inc., Holman, Wisconsin) were positioned around the tree to track her movements. Because of the den tree's proximity to other trees, it is possible that E35 was able to enter and exit the den by climbing to adjacent trees. On 23 and 29 April 2011, we located E35 at the den tree by walking in with the radio-telemetry unit. Between 26 April 2011 and 1 May 2011, E35 was photographed either entering or leaving the den tree on 14 different occasions. Radio-telemetry triangulations were conducted on 15, 20, 21, and 25 April and on 5 May 2011. We located E35 by walking in with a radio-telemetry unit on 1 and 2 May 2012. She was located at two trees other than the den tree on both occasions. The maximum distance E35 was recorded away from the den tree was 850 m, on 2 May 2012.

At 0857 CDT on 24 April 2011, an uncollared American Marten was photographed near cavities at the base of the den tree. The uncollared American Marten appeared to be exploring, and was not detected climbing the den tree. At 0842 on 4 May 2011, an uncollared American Marten was photographed ascending the den tree and then descending at 0848 with an American Marten kit in its mouth. An uncollared American Marten ascended again at 0855 and descended with a second kit at 0856. The kits would have been 10–14 days old.

E35 was not detected at the den by telemetry or by any of the cameras that day, and was not detected at the den again until 2146 on 7 May 2011. On 8 May 2011 at 0849, an uncollared male American Marten ascended and immediately descended the den tree. E35 was not detected at the den tree on this day.

The cameras remained at the den tree until 17 May 2011, but E35 was not detected again at the tree. Visual comparison of E35 and the uncollared American Marten from photographs in the exact same position on the den tree showed that the uncollared American Marten was much larger and 18% longer than E35. We therefore determined that the uncollared American Marten was a male. When captured and radio-collared on 18 October 2010, E35 was 61.5 cm long, only 11% shorter than the longest female American Marten (69 cm) measured in the study ($N = 50$). Visual inspection of remote camera photographs and comparison of pelt coloration suggest it was likely that all three observations of the uncollared American Marten were of the same male.

Only female martens (both American Martens and European Pine Martens, *Martes martes*) have been observed rearing pre-weaned kits (Wynne and Sherburne 1984; Henry and Ruggiero 1993*; Henry et al. 1997; Kleef and Tydeman 2009; Erb et al. 2010*). It is therefore likely that the male was killing the kits during the removal and not transferring them to a new den. Remains of the kits were not found at the base of the den tree when an extensive search of the area was completed seven days later. Additionally, E35's telemetered movements became unrestricted within her home range immediately after the predation event (374 m on 5 May, 1362 m on 9 May, 745 m on 10 May, and 945 m on 12 May 2011). Henry et al. (1997) concluded that female American Martens with pre-weaned kits were less likely to frequently move to new maternal dens; Henry et al. (1997) found that the periods spent in the den were longer than the periods spent away.

Male American Marten activity around maternal dens is understudied, as are reasons why some interactions between adult male American Martens and kits are benign or, as we observed, fatal. Information on den site activity during the early part of the American Marten kit-rearing period is limited (Jones et al. 1997) or has been focused on the movements of females (Henry et al. 1997). We have found no documentation of an American Marten female moving another female's kits or of an American Marten male transporting kits to a new den location.

An additional element is that the infanticide occurred after there was an influx of animals on the landscape, potentially increasing competition for resources. The translocation of an already fertilized female into a resident male's territory could have triggered an infanticide response. Conversely, infanticide could be a mechanism used by males when they usurp the breeding territories of other males, whether it is a resident taking another resident's territory or a translocated animal taking the territory of a resident.

Understanding whether this was an isolated infanticide event, part of normal American Marten territorial

behavior, or the result of the translocation could be informative for management of threatened American Marten populations elsewhere.

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Golden Eagles (*Aquila chrysaetos*) Breeding in Wapusk National Park, Manitoba

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The North American subspecies of the Golden Eagle (*Aquila chrysaetos*) is of conservation concern throughout Canada. The species is not currently known to breed in Manitoba. In 2011 and 2012, during the course of surveys in Wapusk National Park of Canada in northeastern Manitoba, seven pairs of Golden Eagles and one sub-adult were observed. The identification of nests in proximity to three pairs, the presence of an adult at one nest, and visible white down feathers on two nests confirm breeding and extend the breeding range of the Golden Eagle into Manitoba, where breeding was previously uncertain. The three occupied nests were 14 km ($n = 2$) and 31 km ($n = 1$) from the nearest adjacent occupied nest identified. Foraging on Canada Goose (*Branta canadensis*) goslings was observed. Further research is needed to determine the overall nest density and the diet of Golden Eagles in northeastern Manitoba.

Key Words: Golden Eagle; *Aquila chrysaetos*; Wapusk National Park of Canada; nests; range; breeding; Manitoba

The North American Golden Eagle (*Aquila chrysaetos canadensis*) is a far-ranging migratory bird. Its conservation depends on the protection of habitat in Canada and in the United States. Breeding for the larger western populations is reported from Alaska south to central Mexico, with scattered breeding extending east to the border of Saskatchewan and Manitoba (Figure 1A) (Kochert et al. 2002). The smaller eastern population is estimated at only 1000–2500 individuals and currently breeds mainly in Quebec, but some breeding is reported in Ontario and in Labrador in Newfoundland and Labrador (Figure 1A) (Sutherland 2007; Katzner et al. 2012). Management of these eastern Golden Eagles requires a better understanding of their distribution, habitat requirements, and abundance (Katzner et al. 2012).

Overall, Golden Eagles are rare in Manitoba and are mainly observed during spring and fall migration and in winter in the southwestern portion of the province (Manitoba Avian Research Committee 2003). Two historical nesting records from Manitoba, along the Cochrane River north of Brochet and at Hell's Gate Gorge (Figure 1A), are cited repeatedly in birding reference books (e.g., Godfrey 1966; Godfrey 1986; Manitoba Avian Research Committee 2003), but there is a lack of contemporary evidence of nesting in the province. Golden Eagle breeding status in the province as a whole is uncertain (Manitoba Avian Research Committee 2003). This species is uncommon but increasing in the area around Churchill, Manitoba, but without confirmed breeding (Chartier 1994; Jehl 2004).

In 2011, the Manitoba Breeding Bird Atlas, as part of its work across the province, embarked on a five-year

collaborative field effort with the Parks Canada Agency to conduct breeding bird surveys in Wapusk National Park of Canada on the western shore of Hudson Bay. Through this work, we documented breeding evidence of Golden Eagles along the Owl River and the Broad River.

Methods

Study area

The study area is in northeastern Manitoba, in and around Wapusk National Park (N58°, W93.5°) (Figure 1B). Characterized by extensive fens and bogs, Wapusk National Park extends from the northern boreal forest in the southwest to the tundra in the northeast. The area is devoid of cliffs, and the land slopes gently from sea level along the shore of Hudson Bay to less than 100 m above sea level in the southwestern area of the park (Dredge and Nixon 1992). Large trees—White Spruce (*Picea glauca*), Black Spruce (*Picea mariana*), and Tamarack (*Larix laricina*) (Brook 2001)—are mainly found along the banks of the rivers and creeks and in narrow bands around lakes.

Field methods

Avian researchers surveyed portions of Wapusk National Park in June 2011 and 2012 (Figure 1B). Due to the remoteness of the park, survey routes were planned to include canoeing on rivers and cross-country hiking. The area along the Owl River was surveyed in 2011 from the railway tracks (which run from Churchill south to Bird, Manitoba, parallel to the western boundary of the park) east to the shore of Hudson Bay. In 2012, surveys were conducted from the M'Clintock station stop

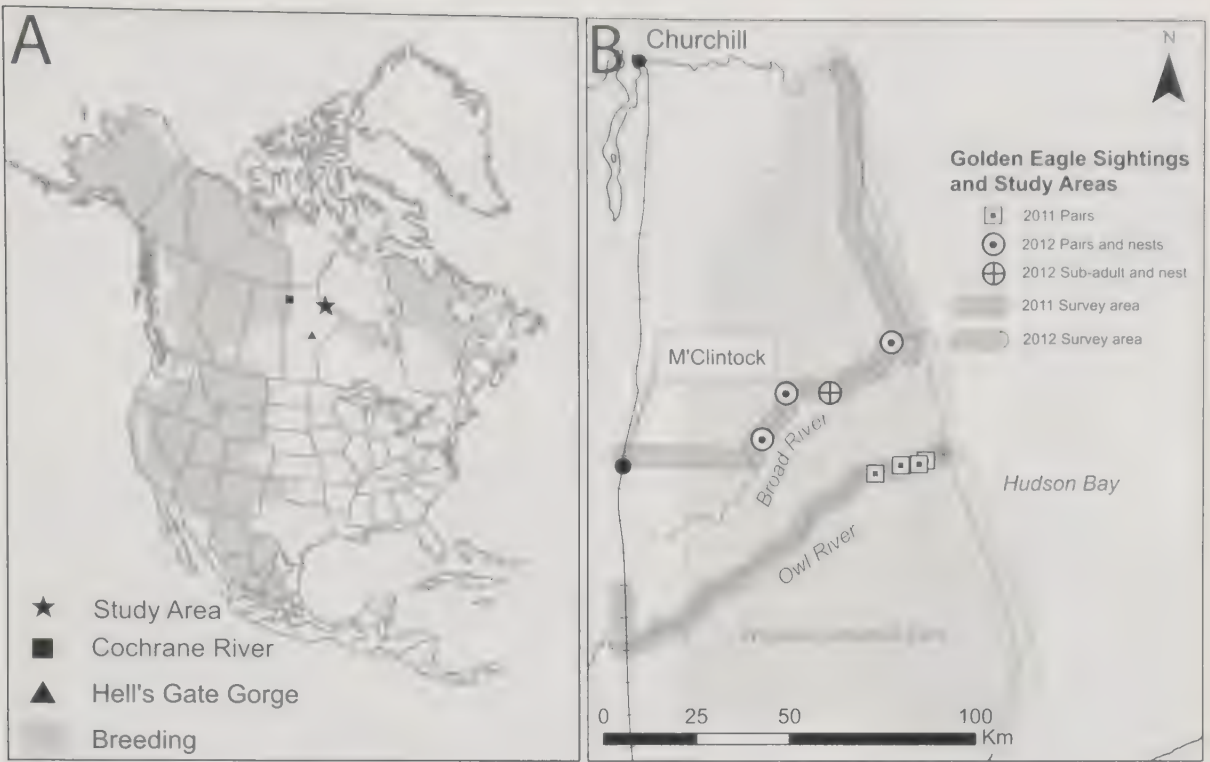


FIGURE 1. North American Golden Eagle (*Aquila chrysaetos canadensis*) breeding range (created using map data from Kochert et al. (2002) and Katzner et al. (2012)) and approximate locations of two historical nesting records in Manitoba (Cochrane River and Hell's Gate Gorge) from Godfrey (1986) (A). Locations of the Golden Eagles, nests, and Manitoba Breeding Bird Atlas areas for June 2011 and June 2012 in Wapusk National Park, Manitoba (B).

to the Broad River, along the Broad River to Hudson Bay, and north along the shoreline to Cape Churchill.

From 15 to 25 June 2011 and from 5 to 12 June 2012, the research team worked on and along the Owl River and the Broad River, respectively (Figure 1B). In the mornings, avian point counts (methods described in Manitoba Breeding Bird Atlas 2011*) were completed on foot. The survey team canoed to the next camp in the afternoon. Sightings of birds of interest, namely rare species (e.g., Golden Eagles) or species listed under the federal Species at Risk Act, were recorded consistently throughout the field work. Upon confirmation of a Golden Eagle sighting, the research team attempted to locate a nest nearby.

The locations of the point counts, sightings of Golden Eagles, and nest sightings were geo-referenced in the field with a Geographical Positioning System (GPS) unit and subsequently mapped in ArcGIS 10.0. The distances between adjacent occupied nests were measured in ArcGIS 10.0.

Results and Discussion

Four pairs of Golden Eagles were sighted on the Owl River in 2011 (Figure 1B). Each pair undertook behaviour suggestive of breeding upon approach by canoe. Specifically, the Golden Eagles moved farther off and

circled as a pair. We were unable to locate nests, and these sightings were thus deemed to indicate probable breeding (as per Manitoba Breeding Bird Atlas 2011*).

In 2012, three pairs of Golden Eagles and one sub-adult (3–5 years old) Golden Eagle were sighted along the Broad River (Figure 1B). We found a stick nest near each of the three pairs sighted (Figures 2A, 2B, and 2D), and a partially constructed eyrie was located near the sighting of the sub-adult (Figure 2C). An adult Golden Eagle flew off one of the nests (Figure 2B) as we approached by canoe.

The three nests associated with mature pairs were constructed of sticks of the right size and shape for Golden Eagles and had the overall appearance of Golden Eagle nests (as opposed to Bald Eagle (*Haliaeetus leucocephalus*) nests) (Todd Katzner, personal communication, 18 January 2013). The presence of white down feathers on two of the nests (Figure 2A and 2D) is indicative of breeding in the current year, and the presence of adult Golden Eagle feathers further differentiates these nests from Bald Eagle nests (Todd Katzner, personal communication, 18 January 2013). The collective weight of this evidence leads us to the conclusion that Golden Eagles are breeding in Wapusk National Park, northeastern Manitoba (as per Manitoba Breeding Bird Atlas 2011*).



FIGURE 2. Three active North American Golden Eagle (*Aquila chrysaetos canadensis*) nests (A, B and D) and one partially constructed eyrie (C) found in Wapusk National Park, Manitoba, 2012.

For the three nests associated with pairs, the distances to the nearest adjacent nest identified were 14 km ($n = 2$) and 31 km ($n = 1$) (Figure 1B). Based on an extensive inventory of Golden Eagle nesting areas along Hudson Bay in northern Quebec, Morneau et al. (1994) reported similar distances to adjacent nests (range 9.8–44.7 km, $\bar{x} = 26.5$, $SD = 11.0$, $N = 16$). No other nests were identified during our work. A systematic survey is needed to determine the overall Golden Eagle nest density.

All four nests were in White Spruce trees along the north bank of the Broad River and approximately 5 to 10 m above the ground (Figure 2). The three nests associated with breeding pairs were in the top half to top third of the trees, with generally southern exposures. The third active nest was the largest (estimated >1 m in depth). This nest contained at least two ages of sticks, and two platforms were visible (Figure 2D). As Golden Eagles re-use nests and add to their nests over the years (Kochert et al. 2002), we estimate the third active nest had been used for multiple years. Due to the number of mature Golden Eagles observed over the two

years of the survey (seven pairs) and the size of the third active nest described above, we hypothesize that these sightings do not imply a recent change in distribution of the species but rather are likely the result of increased search effort in a remote region.

Katzner et al. (2012) describe the breeding habitat of the eastern population of the Golden Eagles in northern Quebec, Ontario, and Labrador (Newfoundland and Labrador) as the “interface of tundra, boreal forest and wet meadows” (page 170), an apt description of the study region in Wapusk National Park. The nearest probable and confirmed breeding evidence from the second Ontario Breeding Bird Atlas was approximately 320 km and 550 km, respectively, southeast of our study area, with most nests on bedrock cliffs and less commonly in tall riverside spruce at the tundra–boreal ecotone (Sutherland 2007). Satellite tracking or genetic analysis may be useful in identifying the migration routes and wintering grounds of the Golden Eagles we observed in Wapusk National Park and in determining whether they are more closely related to birds from the west (i.e., Saskatchewan) or from the east (i.e., Ontario).

The partially constructed eyrie differed from the three nests associated with breeding pairs in that it was smaller and in poorer condition (i.e., the branches were not tightly packed and there was a hole in the bottom of the nest) (Figure 2C). In contrast to the other three nests, it was constructed near the top of the tree, in branches that likely could not support an active nest. We hypothesize this nest may have been built by the sub-adult eagle to establish a nesting territory for future years, as has been suggested for a sub-adult Bald Eagle in British Columbia (Forbes and Kaiser 1984). As Golden Eagles build alternate nests in their breeding territories (McGahan 1968; Fasce et al. 2011; Kochert and Steenhof 2012), other possibilities are that this nest was built by a mature breeding pair or that it was a partially collapsed nest, now abandoned, that proved attractive to a sub-adult bird. This nest may also have been built by another species, possibly Bald Eagles.

Throughout their range in North America, Golden Eagles generally nest on cliffs (Kochert et al. 2002), including near Hudson Bay in northern Quebec (Morneau et al. 1994) and along the Churchill River in Saskatchewan (Whitfield et al. 1969). Nesting in trees is rarer, but it has been documented in Ontario (Lumsden 1964; Sutherland 2007), Montana (McGahan 1968), and in the Gaspésie in Quebec (Brodeur and Morneau 1999*). Nests on the ground are used in some areas (Menkens and Anderson 1987), but tree sites provide better protection from predators.

As nests can weigh hundreds of kilograms (Watson 2010), tree nesting is limited by the availability of trees that can support this weight. A variety of tree species are used in North America, including deciduous trees (Menkens and Anderson 1987), Eastern White Pine (*Pinus strobus*) (Brodeur and Morneau 1999*), and Ponderosa Pine (*Pinus ponderosa*) (Menkens and Anderson 1987). Our observations of nests in White Spruce can likely be attributed to these being the largest trees in a region lacking suitable cliff sites.

The four pairs of Golden Eagles observed along the Owl River in 2011 were first observed flying low above the river where recently hatched Canada Goose (*Branta canadensis*) goslings were swimming. We observed one gosling falling prey to a Golden Eagle, and we hypothesize young geese are likely an important food source. Along the arctic coast in the central Northwest Territories, Poole and Bromley (1988) determined Arctic Hare (*Lepus arcticus*) was the main prey item for Golden Eagles but waterfowl, mainly Canada Geese and eiders (*Somateria* spp.), accounted for 40% of the diet.

Birds are the main prey of Golden Eagles breeding near Hudson Bay in northern Quebec (Brodeur and Morneau 1999*). Arctic Hares (Dubois and Monson 2004), Canada Geese, and eiders (Rockwell et al. 2009) are found in Wapusk National Park, and we hypothesize that these may form part of the Golden Eagle's diet in the region. There are also large nesting colonies of Lesser Snow Geese (*Chen caerulescens caerulescens*)

in Wapusk National Park (Rockwell et al. 2009). Further research is needed to determine the diet of the Golden Eagle in the region.

Our identification of tree-nesting Golden Eagles in Wapusk National Park, northeastern Manitoba, extends the known breeding range of this species. Further research is needed, through a dedicated survey, to determine the extent of the nesting areas and the number of birds nesting and to characterize nest sites and nesting habitat in Manitoba. On a larger scale, further research is needed to determine the migration routes and wintering grounds of these Golden Eagles and thus support international conservation efforts.

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First Nesting Records for the Short-eared Owl, *Asio flammeus*, on Banks Island, Northwest Territories: Evidence of Range Expansion to Arctic Islands in Canada

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Two Short-eared Owl, *Asio flammeus*, nests were discovered in the summer of 2000 along the Thomsen River in Aulavik National Park of Canada on Banks Island, Northwest Territories. One other sighting of a Short-eared Owl suggests the possibility of a third breeding pair. These nests are the first confirmed breeding evidence from islands in the Canadian Arctic Archipelago.

Key Words: Short-eared Owl; *Asio flammeus*; nest; range expansion; Aulavik National Park of Canada; Banks Island; Northwest Territories

Short-eared Owls, *Asio flammeus*, are highly nomadic, following fluctuating food resources and frequently breeding and wintering where numbers of small mammals are particularly high (Wiggins et al. 2006). Short-eared Owls are known to breed in suitable habitat throughout Canada, with the exception of the Canadian Arctic Archipelago (Committee on the Status of Endangered Wildlife in Canada 2008*). Suitable habitat in the Arctic includes coastal estuaries, tundra with areas of small willows and dense grasslands (Committee on the Status of Endangered Wildlife in Canada 2008*).

Since the mid-1970s, a number of biological surveys have listed species of birds for Banks Island, Northwest Territories (Wilkinson et al. 1977*; Zoltai et al. 1980*; Henry and Mico 1997*), but none documented the presence of Short-eared Owls. Raptors include the fairly common Snowy Owl (*Bubo scandiacus*) and Rough-legged Hawk (*Buteo lagopus*), the less common Peregrine Falcon (*Falco peregrinus*), and the rare Gyrfalcon (*Falco rusticolus*). In the summer of 2000, however, Short-eared Owls were documented for the first time on Banks Island.

Observations

The first of two Short-eared Owl nests was discovered on 25 June 2000 near Green Cabin on the Thomsen River (73.236°N, 119.545°W) in Aulavik National Park of Canada (Figure 1) and reported to park authorities. Green Cabin is a patrol/research cabin upstream of Dissection Creek. On 27 June, when we approached the nest, the male flew off from a location about 100 m from the nest. A subsequent inspection of the site where the male had flown up from revealed the head of a lemming,

with the body missing. The incubating female (Figure 2) did not leave the nest until we were within about 3 m. There were seven eggs in a nest bowl lined with dried grasses and a few feathers (Figure 3). The nest was in a low space between tundra hummocks on the edge of a wet sedge meadow (Figure 2). There were two Common Eider (*Somateria mollissima*) nests within 20 m of the Short-eared Owl nest.

The following morning (28 June), an Arctic Fox (*Vulpes lagopus*) was observed hunting in the area for about half an hour, and both adult Short-eared Owls harassed it during that time, constantly swooping at it. The Arctic Fox disappeared from sight, then came into view again at the same time that a female Common Eider flew to a nearby pond. A check of the nest later the same day revealed that the Short-eared Owl was still incubating, but the nearest Common Eider nest had been predated. The Short-eared Owl nest was not checked again until August 10, at which time it was empty. Because we did not know the date on which the female began incubating, and the fact that nestlings will move some ways from the nest as young as 14–17 days of age (Committee on the Status of Endangered Wildlife in Canada 2008*), we cannot say whether the nest was successful or not, although the timing makes it possible.

The second Short-eared Owl nest was discovered on 23 July 2000, approximately 4 km downstream of the confluence of the Muskox River and the Thomsen River (73.856°N, 119.854°W), also in Aulavik National Park. Two adults were observed, and there were four pink-to-downy young in the nest. On both 27 and 28 July, a single adult was seen hunting in the meadows in the area. Since only the female is known to incubate



FIGURE 1. Location of the two Short-eared Owl, *Asio flammeus*, nests (black circles) and single observation (open circle) in Aulavik National Park of Canada, Banks Island, Northwest Territories, in June and July 2000; the observations by Reid et al. (2011) on Herschel Island, Yukon (black triangle); and the observation by Therrien (2010) on Bylot Island, Nunavut (black square). Dashed line shows northern limit of breeding range in Canada (Wiggins et al. 2006); question marks indicate possible breeding areas (Wiggins et al. 2006). Map adapted from Wiggins et al. (2006).

(Wiggins et al. 2006), we presume this was the male. It was periodically followed and dive-bombed by a Pomarine Jaeger (*Stercorarius pomarinus*). This nest was approximately 70 km north of the nest near Green Cabin.

On 2 July 2000, an adult was observed flying across the Thomsen River, between White Sand Creek and Shoran Lake (73.436°N, 119.688°W). Because of the distance from the Green Cabin nest (23 km) and the Muskox River nest (47 km), this observation might indicate the presence of a third breeding pair of Short-eared Owls. Holt (1992) reported territory sizes of up to 242 ha in various studies.

In 2000, we also observed the following species for the first time on Banks Island, near the community of Sachs Harbour (71.986°N, 125.250°W): Merlin (*Falco columbarius*), Yellow-rumped Warbler (*Setophaga*



FIGURE 2. Short-eared Owl, *Asio flammeus*, female on nest (circle) near Green Cabin, Aulavik National Park of Canada, Banks Island, Northwest Territories, 27 June 2000. Photo: C. M. Smith.

coronata), Chipping Sparrow (*Spizella passerina*) (June 11), and White-throated Sparrow (*Zonotrichia albicollis*) (June 22). All four species were from 400–750 km farther north than their known breeding ranges



FIGURE 3. Short-eared Owl, *Asio flammeus*, nest near Green Cabin, Aulavik National Park of Canada, Banks Island, Northwest Territories, with seven eggs, 27 June 2000. Photo: C. M. Smith.

Discussion

The observations reported here confirm breeding by Short-eared Owls in the Canadian Arctic Archipelago, over 500 km north of the mainland. Along with the three nests documented on Herschel Island, Yukon, in 2007 and 2008 (Reid et al. 2011) and territorial behaviour observed on Bylot Island, Nunavut, in 2008 (Therrien 2010), these observations may provide evidence of northerly range expansion by this species. It is also possible that Short-eared Owls have been breeding on the islands for decades, but limited survey effort meant they were undetected. These may also have been extralimital breeding episodes in response to high numbers of prey (Pitelka et al. 1955; Reid et al. 2011), mainly Nearctic Brown Lemmings (*Lemmus trimucronatus*) and Northern Collared Lemmings (*Dicrostonyx groenlandicus*). In 2000, twice as many lemming nests were observed on monitoring plots near Green Cabin as in 1999 (Lawrence 2000*).

If this is a range expansion, it may be related to climatic factors. A rise of 2–3 Celsius degrees in mean annual temperature has been observed over the past 50 years in the western and central Canadian Arctic (Zhang et al. 2000; Furgal and Prowse 2008), and one of the

biological responses is that the ranges of many species of plants and animals are expanding northward (Thomas and Lennon 1999; Intergovernmental Panel on Climate Change 2001; Parmesan and Yohe 2003; Brommer et al. 2012). The observations of the Merlin and three passerines for the first time on Banks Island support the hypothesis that climate change enabled the range expansion of the Short-eared Owl.

The Short-eared Owl is listed under the federal Species at Risk Act as a species of “special concern” because of population declines attributed to habitat conversion/degradation on both the wintering and the breeding grounds (Committee on the Status of Endangered Wildlife in Canada 2008*). It is unknown to what extent range expansion in the islands in the Arctic might compensate for this loss.

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Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

Editor's Note. The address of the Birds of Northumberland County website has been changed to <http://www.willowbeachfieldnaturalists.org/NorthumberlandCounty>. This is part of the Willow Beach Field Naturalists' website, but the URL above will take you directly to the Birds of Northumberland County. Please note that the URL is case sensitive. From Clive Goodwin.

ZOOLOGY

The Unfeathered Bird

By Katrine van Grouw. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540. 289 pages, 49.95 USD, Cloth.

Illustrations of birds have long provided some of the most enduring, popular and informative natural history books. Artists and naturalists, such as John James Audubon and Roger Tory Peterson, popularized ornithological artwork as a means of providing the reader with a resource which he or she could use to identify the birds that they themselves encountered. *The Unfeathered Bird* is a unique book incorporating beautiful artwork, biological fact and historical anecdotes. But Katrine van Grouw (a former curator of the ornithological collections at the Natural History Museum in London, England) has provided the reader with a uniquely memorable collection of illustrations accompanied by accessible text, which should be considered one of the finest combinations of art and science available.

The Unfeathered Bird's first line denounces that "This book is not an anatomy of birds". When Von Grouw began this project twenty-five years ago, she intended it to be a book for artists, before realizing the far-reaching appeal of a book of this nature. Containing no biochemistry, Latin, scientific jargon and little in the way of physiology, the book does provide a comprehensive tour of the external anatomy of this remarkable group of organisms, drawing from the artist's extensive ornithological knowledge in providing a text that is deliberately concise, flowing, and accessible. The book is divided into two main sections: the shorter part 1 is 'Generic', introducing anatomical features common to all groups of birds, whilst the much longer part 2 is 'Specific', guiding the reader through individual groups, relating their evolution and behaviour to their physical structure and appearance.

The 385 sketches and paintings, depicting 200 species from all over the worlds (including many never illustrated before), are unrivalled in their texture and accuracy. During the twenty-five years that it took to produce this work, van Grouw and her husband pre-

pared specimens of birds, all of which died from natural causes and were donated by the finder, and arranged them in life-like poses. During this preparation, birds were stripped of their feathers, skin and often flesh, resulting in hauntingly beautiful and astoundingly detailed images. For the first time on the printed page, true-to-life-size images, sometimes capturing an individual engaging in natural behaviour unique to each species, are provided to best demonstrate the most obvious adaptations to their particular environment. Some of my favourite sketches included the three barn swallows perched on a wire (seemingly more precariously than if their feathers were present!), and the double-page spread of finches, clearly showing a range of bill shapes in European species and the consequences of adaptive radiation in Darwin's Galapagos finches.

The up-to-date, scientifically rigorous text succeeds in its objective of omitting the impenetrable jargon that is found in many anatomical or ornithological works. Instead it clearly provides the general reader with lively dialogue outlining the theoretical reasons for the structural and behavioural differences between the many groups of birds that are illustrated. In grouping together bird groups by convergent evolution in the 'Specific' section (e.g., placing swifts next to swallows or storks next to cranes), the author has deliberately highlighted the ever-changing debate and discovery that is the field of taxonomy. Van Grouw also integrates insightful historical anecdotes, enlightening the reader further on the routes of discovery that ornithologists have taken in furthering our understanding of these unique organisms.

The Unfeathered Bird, the culmination of a lifetime of work by the author, is a rare gem that would be equally at home on an artist's coffee table as it is on a biologist's bookshelf. One can simply browse the fascinating and sometimes macabre illustrations or engage in

the highly readable but mentally stimulating text, and can certainly do both. *The Unfeathered Bird* is a landmark piece that successfully bridges art, science and history, in a beautiful and accessible package that will no doubt be treasured by anyone whose path it crosses.

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Biology and Conservation of Martens, Sables and Fishers – A new synthesis

Edited by K. B. Aubry, W. J. Zielinski, M. G. Raphael, G. Proulx and S. W. Buskirk. 2012. Comstock Publishing Associates, Box 6525, 750 Cascadilla Street, Ithaca, NY, USA, 14851-6525. 580 pages, 75.00 USD, Cloth.

This book is a synthesis of the invited, oral presentations from the Fifth International *Martes* Symposium held in September 2009. It reflects a very broad range of the current knowledge, often acquired with techniques not available prior to the first book of this nature in 1994. There are five sections to this book, but such a broad overlap between the sections exists that I don't think they were the best choices; this does not detract from the individual papers at all, but the organization is just a bit odd. These are scientifically written papers, and as such, are directed at peers and serious naturalists.

There are a few technical points which bothered me. In the vast majority of scientific writings, the whole numbers one through ten are spelled out, not written as numbers. For long-time readers of science, seeing "5" instead of "five" gives rise to a reading hiccup. It's also really quite irritating to find a graph axis labelled 0.6, 0.8, 1, 1.2, etc. Authors creating the graphs simply accepted sloppy defaults, where they should have insisted on consistent decimal places (e.g. 1.0, not 1) throughout. However, the papers are otherwise quite well written and make the arguments effectively.

The first paper, *Synthesis of Martes Evolutionary History* sets the stage for the animals discussed in this tome. Although the relationships *within* the genus are well described, a cladogram and brief discussion of the context of the genus *among* other mustelids would have been appropriate. The reader is exposed here to the possibility that the Wolverine and the Tayra may, with more analysis, be included in *Martes*, but where are the otters, badgers and weasels relative to the martens and their kin?

There are two papers centring on parasites; curiously, the one entitled *Complex Host-Parasite systems in Martes: Implications for Conservation Biology...* does not appear in the section on conservation. None-the-less, both papers are well-written and quite interesting (no, this reviewer is not a parasitologist!). The second paper by Gabriel, Wengart and Brown includes a massive table of presumably all the known parasites associated with the genus...a total of almost 250 host-parasite relationships. This table alone would be gold

to someone starting out in *Martes* parasitology.

The chapters on habitat use bring to light the unexpected result that these animals are not, as presumed, dependent on old growth forests, neither in Europe nor North America. Given the lack of old growth, this is good news for reintroduction programs. However, the general consensus is that when available, complex forest structure, often found in old growth is preferred.

The section on research techniques includes chapters covering the gamut from scat-detecting dogs through radiotelemetry and modelling. In most cases, historical techniques (i.e. prior to 1994) are compared with current ones. Advantages and disadvantages of each technique are often discussed, allowing the reader to critically assess them.

The final section contains five chapters dealing with the conservation of *Martes* populations. The opening chapter, although well written, contains disappointing maps...pixellated and, in the case of the North American maps, uses projections which emphasize the United States, a country largely devoid of these animals, and a compressed Canada, where most of the detail is really necessary. Two graphs within this chapter have seven curves each, giving rise to an unnecessary amount of clutter. This could have been done better.

There are two strengths associated with reviews or amalgams of papers like this one (which include reviews). The first is that the reader gets the opinions of a diversity of authors, in this case, 62 of them. The second is the wealth of literature cited...a boon to anyone doing this type of research, whether a novice or career *Martesologist*. This volume cites over 1600 works... could a single paper have been missed?

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Buskirk, S. W., A. S. Harestad, M. G. Raphael and R. A. Powell (editors). 1994. *Martens, Sables and Fishers: Biology and Conservation*. Cornell University Press, Ithaca, NY.

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Mammals of China

Edited by Andrew T. Smith and Yan Xie. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA. 08540-5237. 396 pages, 24.95 USD, Paper.

This book arrived just before I left for Mongolia. Not quite China, but I thought it would be worth testing in the field. I was not disappointed. Many mammals are shared by both countries. Even the range maps were useful as a south China species was not likely to occur inside its northern neighbour. I saw 12 species of mammal and photographed nine. I was able to confirm my identifications with a government naturalist. So I think this book works well.

It was originally issued as a larger, hard covered book in 2008. I said then "This is a much needed guide and it will be indispensable for naturalists and mammalogists for years to come." This paperback version covers all of China's 558 species of mammals in a handy-sized book. Each species has the English, Chinese (in Chinese characters and transliterated) and scientific name, but the text is all in English. The brief description focuses on the key identification characteristics. The Chinese range is given on a map. The world distribution is given as text – most useful in Mongolia. The creature's natural history tells of its habits, food, habitat, and reproduction.

The artwork is from the 2008 book and is excellent (by Federico Gemma). A comparison of the mammals with which I am most familiar showed the paintings to be accurate in shape and colour. However the reader should be warned that not all the species are illustrated.

For example only eight of the 22 species of *Pika* are shown. So the written descriptions are critical. The illustrations are next to the text (not in a plates section as in the original book) and this is much more practical for a field book.

The range maps are still a little confusing. The authors state "the maps depict the original distribution ... before contraction ... due to anthropogenic factors." Yet they also say "the distribution ... in the most accurate form possible at the present time." I find these statements a little at odds. What I want is the current distribution, not the historical range. The authors, for reasons they define, use the actual location of each of an accurate record (specimen etc.) as a dot. I would still prefer a best guess given as a shaded zone.

I checked the two errors I noted in the original text. They are still there (for example Savi's pipistrelle occurs in the Mediterranean region of southern Europe, as well as northern Africa, the Middle East, Asia, Mongolia and Japan – not in Northern Europe.)

I still think this is a great book and it is now more portable. I will take on my upcoming visit to China next spring.

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Odd Couples

By Daphne J. Fairbairn. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 300 pages, 27.95 USD, Cloth.

Odd Couples is a very informative and enjoyable book for anyone interested in animal life history. The focus of *Odd Couples* is the question of how differences between the sexes in the animal kingdom are adaptive to the roles that each sex plays in the species life history. The differences presented in this book are not the obvious differences in sexual organs but the differences in body size, shape, and color. It also presents a careful examination of differences in behavior, movements, food habits, reproductive capacity, and other life history characteristics. These are all important to questions in evolutionary biology.

The author's goal in writing this book was to provide a readable book for both professional and lay readers. To this end she has been very successful. The book is well written for both audiences but is also thoroughly documented with notes and a complete list of references that permits the professional to track down the sources for all statements. A glossary provides another valuable element for the reader.

Individual chapters present a complete discussion of sexuality in elephant seals (*Mirounga* sp.), great bustards (*Otis tarda*), a cichlid fish (*Lamprologus callipterus*), yellow garden spiders (*Argiope aurantia*), blanket octopi (*Tremoctopus* sp.), giant seadevils (*Ceratias holboelli*, an anglerfish), bone-eating tubeworms (*Osedax* sp.), and shell-burrowing barnacles (*Trypetessa lampas*). Each species was selected by the author to represent the extremes in sexual characteristics among animals. Other chapters provide important background and general concluding remarks that help to set the stage as well as conclude the book.

Overall this book is very free of noticeable errors in spelling and is sturdily bound. I can recommend it for any interested naturalist whether professional or non-professional.

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Wildlife of Australia

By Iain Campbell and Sam Woods. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA. 08540-5237. 288 pages, 19.95 USD, Paper.

The authors state the book is designed for travellers so they have restricted the species presented as those that people will likely see on a typical visit. This is a good concept.

They state they cover 70 mammals (out of a possible 379), but it was clear this was not correct. I counted 40 species and maybe could stretch it to a few more for mammals that were mentioned in the text. The same applied to the other animals. As I thumbed through I saw that two birds (page 192) were incorrectly identified. I decided to check a few other species and used the index. I soon realized the index has serious problems. Most entries that identify pages for plates (in bold) are 11 pages too low. Pages in non-bold are correct for the text. I checked several entries at random and two were correct (Mangroves and Coastline on page 6). The rest had errors. The worst was the Brown Booby which is on page 76 not on 74 or 66 as given in the index. While Mangroves and Coastline are in the index other habitats are not (Karri Forest, Tropical Savannah etc.)

Ignoring these technical glitches, how well does the book work? For the mammals it makes sense to limit the guide to the big, obvious beasts. There are only three species of bat covered out of a possible 57. These are the large flying foxes. The same is true for the 12 snakes – out of about 60 species. Similarly they have chosen 11 species of native frog and 1 introduced species, the infamous Cane Toad (out of 230). For the birds they have been more generous illustrating not the 350 claimed but 320 species. This is about 40 % of Australia's total.

The book is in typical field guide format – a brief text on the left and illustrations on the right. The text discusses identifying features, habits and habitats, and where it is found. In some instances a similar species is discussed, but not illustrated. The ranges are given using codes that are not explained until you reach the abbreviations page at the back of the book. As there are only seven states and territories it is simple to work out these codes.

The text is well written and informative giving salient points of identification and range. The photos are good quality portraits taken by 16 photographers. There is only one illustration per species, generally the male. Therefore you need to check the text for sexually dimorphic birds. For example, the Eastern Koel is a nice picture of a brown, speckled female. You need to read that the male is “all glossy black with a blood red eye.”

The book starts with a vegetation map of Australia, showing ten zones. Then the authors describe 23 habitats, but these do not correlate with the map. For the new visitor these descriptions are useful and include the keynote species that live there.

This is a book of good intentions that does not quite make it, due to some poor organization and editing. It could be used in the field and its size and the limited number of species are good features for the travelling naturalist. I think I would still take at least a copy of the *Birds of Australia: (Princeton Field Guides)* by Ken Simpson and Nicolas Day so I have access to ranges, multiple plumages and regional variations.

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BOTANY

Aldrovanda, The Waterwheel Plant

By Adam Cross. 2012. Redfern Natural History Productions, 61 Lake Drive, Hamworthy, Poole, Dorset, England, UK. BH15 4LR. 249 pages, 61.08 USD, Cloth.

This is the first comprehensive monograph of the Waterwheel Plant. It shows a small, submerged, carnivorous plant which is rarely seen due to its specialized habitat and also because it is on the verge of extinction. Adam Cross, who was still in PhD studies at the time of writing, shows not only the uniqueness of a rare plant in his monograph, but also the ecology of wetlands which are rapidly changing and the limited abilities of rare plants to keep up with that process of change.

He begins with the work of Charles Darwin, who studied this plant from his lab in England in the mid eighteenth century though the plant is not a native English species. Darwin liked to study carnivorous plants

and so gave some of the first descriptions of the Waterwheel Plant's ability to grab mosquito larvae and consume it to supplement its restricted photosynthetic abilities. From the 19th century to modern research, Cross follows the progression of science and brings us to biochemical and physiological mechanisms which govern its carnivorous actions of grabbing prey, choosing prey and biogeography.

Biogeography then becomes the main focus, listing *Aldrovanda's* particular chemical needs, its *niche* requirements and its dispersal patterns, mostly by avian migrants. A detailed list of sites from world herbaria follows the collection record of the species through Europe, Asia, Africa and Australia over the past two

centuries. North and South America have never had naturally occurring populations. The next chapter explains its genetic diversity or lack thereof using current studies of protein chemical differences as well as the makeup of chloroplastic and mitochondrial DNA. His thesis focuses on the increasing lack of diversity due to diminishing samples and the vectors necessary to disperse the remaining populations throughout the world.

The last part of the book is dedicated to cultivation of *Aldrovanda* in tanks, labs, and greenhouses. Previous conservation and management initiatives have been only incidentally successful and changes in drainage patterns in the lands where the species has occurred naturally have resulted in its disappearance from a local lake, or a geographic area and in some cases like Japan, an entire country where it was once collected frequently. New introduction techniques are described but most-

ly the time-proven conservation strategies are regarded as being the most successful in sustaining local or world populations.

For a floating, submerged plant which is only 1.5-3 cm across and 10-20 cm long with the ability to consume small insect larvae by snapping its leaves shut on the victim, and occasionally but not often flowering and setting seed, this is a remarkable plant. Plants under our feet, floating in muddy parts of the swamp where no one except botanists care to tread continue to fascinate us and bring us exciting examples of the biodiversity around us. The Waterwheel Plant is a fascinating study combining older research techniques with modern biochemical revelations and is a detailed but fascinating read for any botanist.

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OTHER

Antarctica – Global Science from a Frozen Continent

Edited by David W. H. Walton. 2013. Cambridge University Press, University Printing House, Shaftesbury Road, Cambridge, UK, CB2 8BS. 342 pages, 35.00 GBP, Cloth.

When I was first offered the opportunity to review this new book, I was a bit reluctant as I didn't feel qualified to peer review scientists who are experts in their field, but upon reflection, it became clear that a layperson, who knows something about Antarctica, is exactly the right one to assess this book. Why? Well, because if I can understand these complex concepts then they've done their job well. The book is edited by Professor David H. Walton of the British Antarctic Survey, well-respected for his expertise on Antarctica. He is joined by thirteen co-authors from around the globe, each of whom has added a chapter focussing on their area of expertise.

I wasn't exactly sure what the intended focus of the book was or who the target audience would be, so I read it presuming it was designed for academia AND people generally interested in Antarctica. This presumption served me well for each will have an interest in different parts of the book.

Dr. Walton opens the book with a brief but interesting history of the early exploration of Antarctica, starting with the presumed presence of this unknown land, *Terra Incognita*, as early as 1531 and culminating with the establishment of the International Geophysical Year in the 1950s. It is this latter accomplishment that set the groundwork for the protected status Antarctica enjoys today. This was a very interesting chapter and my only wish was that it could have been more inclusive of the details of some of the wonderful expeditions that visited Antarctica and revealed its wonders to us. The author waxes a bit poetic when he publishes two poems about Antarctica that add little value to the book, from my perspective, but do demonstrate the scope of people's interests, particularly from an artistic perspective.

As the chapters unfold, we first learn much about Antarctica through a surprisingly understandable geological overview of this complex continent. The author provides concise information that explains how Gondwana morphed to become, in part, Antarctica and he delves into the secrets hidden under the ice, such as 200 km long Lake Vostok, hidden mountain ranges and fossilized tropical plants and animals, reflections of the landscape that preceded this icy empire. More hints at what lies below are revealed by emergent nunataks, poking their head above the ice, and by active volcanoes in the north that show the restless foundation on which Antarctica sits. It is with this chapter that the reader is tantalized for what is to come. Much of what ensues in the book is about climate change and that is where the value of the book really lies. In the next chapter, the author looks back in time to see what the ice can tell us. Early data, dating back to 800,000 years ago, reveals the chemistry of the air that blanketed Antarctica and rest of the Earth. Comparison with modern day data shows how things have and are changing. The importance of unlikely factors, such as dust from Patagonia, and expected influential factors, such as the albedo of reflective surfaces, provide clues as to why climate change is occurring and what we might expect in the future. The author defines an era, referred to as the anthropocene, where humans are impacting global climate. This concept is built on by other authors as the book progresses. The next offering focuses on how and why the landscape and climate of Antarctica is impacting world climate. The author explains the climatic significance of the winds at this locale and the origins and climatic impacts of the ozone hole. The following chapter introduces the concepts of

how “bottom water” from the Weddell Sea, icy seas, and gyres (i.e. wind driven currents) are influencing world climate.

So let me pause here for a moment and warn the reader that these first chapters are clearly written by scientists, experts in their field and are not written with the “See Spot Run” crowd in mind. Verbiage is scientific, concepts complex and the vocabulary clearly erudite! Nonetheless, what they have to say is important and valuable and I encourage you to wade through them and glean what you can to better understand what is happening to our great Earth.

Now came the part of the book I liked best – the part that dealt with the flora and fauna, both terrestrial and aquatic (benthic and pelagic). A good biological overview of all life, from the microscopic to the macrofaunal is provided in these pages. In this chapter and throughout the book, the pages are adorned with wonderful photographs of the subjects being discussed. The animals, which live in and near the Antarctic, are particularly well illustrated. A very interesting chart is presented that summarizes the biological colonisation and extinctions in Antarctica from the Paleozoic era to the present. There was one descriptive paragraph that I particularly enjoyed as it answered myriad questions in my mind. Sea ice blocks light which should diminish life itself. Right? No wrong – sea ice also encourages the upwelling of nutrients from the depths, which stimulates life and growth. Only one error jumped out at me – the Light-mantled Albatross was incorrectly called the Light-mantled Sooty Albatross. The chapter closes with evidence of how we negatively impact the ecosystems of this frigid land, from the controlled but subtle influence of tourism to the permanent interference of research bases in fragile coastal areas.

The book now drifts back to the highly scientific as the author discusses such matters as radiation belts in space, cosmic rays and “IceCube” neutrinos ... but don’t get me wrong this is an interesting chapter that reveals much about how the world’s climate can be predicted by studying solar and terrestrial influences and the atmosphere above Antarctica. The following chapter is very interesting and focuses on what it is like to live and work in Antarctica. Insights into the facilities where scientists work, what they eat and do and how they entertain themselves are provided in these pages. Many countries own bases to conduct their research, while some invite other scientists, as renters or guests, to use their facilities. Wanna go bowling? Why not visit McMurdo Station for they have a great bowling alley!

Chapter 9 deals with collaborative scientific research, particularly as it relates to SCAR – The Scientific Committee on Antarctic Research, from its beginnings in 1958 to the present where its roles have morphed to where it is now the authority on Antarctic research. Following this, the next author deals in part with the exploitation of Antarctic resources, from seals to whales

in the early days. The complex land claim structure of the Continent and the implications of who claims what are discussed. As time passes and the world’s resources are further diminished, the riches, real or perceived, of Antarctica become more appealing – be it the fisheries, the krill harvest or mineral exploration – all will tax Antarctica and its wildlife. The chapter closes with a discussion of the evolution of the Antarctic Treaty and what it means to the future of Antarctica. The last chapter deals with various climate-related factors, how they are changing and what that means to the future of Antarctica, its wildlife and even the world. The book closes with an all too short discussion about visiting Antarctica. I was pleased to see that my book (“Antarctica – First Journey”) was recommended as required reading for those wishing to visit Antarctica!

Sometimes I like to tantalize the reader and pose some questions, whose answers may be found in the pages of the book I’m reviewing. So here goes ... How does *Aurora australis* impact communication equipment? Which is bigger the East Antarctic Ice Sheet or the West one? Why are there so few creeping decapods (e.g. lobsters and crabs) in Antarctica? Why is the Antarctic ice melting from above and below? Is it a bad thing or a good one that sea polyps are increasing? Why are modern day Antarctic-based research scientists often smelly? Who, in the 1760s, postulated that millions of people lived in Antarctica? Why is the Antarctic older than the Arctic? Why did early explorers create “castles in the sky”?

And just before I wrap up, here are some scary (and good) facts: The ozone hole will start to self-repair in 2 years and by 2099 it should be gone. The rate of rise of CO₂ today is 50 times faster than at any other time in history. 90% of Patagonian Toothfish (Chilean Seabass) is caught illegally. Seawater acidity has increased by 30% since the 1800s resulting in a “noisy” ocean that is negatively impacting whales and dolphins. Transmitters are being attached to Elephant Seals to gather deep water data useful to studying climate change.

Okay time to wrap this up. I liked the book even though some chapters were a bit too much like a university lecture for this former student. I would have liked to have seen a summary chapter that brought the messages of all the chapters into perspective. Where exactly are we with climate change? Is it as bad as it sounds? What can we do? What will Antarctica look like in 100 years? There is a lot of great information here and I must admit that I am now more of a believer in climate change than I was before I started reading this book. It’s scary, but unless we understand the problem, we can never find the solution. If you truly want to gain an understanding of what is happening and why, I would strongly encourage you to read this book.

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For the Birds – Recollections and Rambles

By Fred Helleiner. 2013. Willow Printing and Publishing, Brighton, ON, Canada. Obtain from the author at fhelleiner@trentu.ca 20.00 CAD plus 2.50 CAD for postage and handling or the lighthouse gift shop at Presqu'île Provincial Park. All profits will be donated to the Friends of Presqu'île 25th Anniversary Environmental Fund.

Anyone who has visited Presqu'île Provincial Park in the last few years will know Fred Helleiner. He is the gent who roams the park on his (t)rusty bike carrying a telescope. Everyone who visits the park should stop at Fred's house near the lighthouse and read his bulletin board of daily bird sightings or stop for a chat.

Fred's book chronicles his early start with his interest in, then passion for birds. He details his story along with places and people who influenced his progress. I was only a few pages into the book before I became nostalgic. His tale is, I am sure, similar to many in the same age bracket. I am about 10 years younger than Fred and went through the same stages. I halted at "scorn and derision that were heaped on early birders." This was an age when children who were different were persecuted. In my pre-teen and teen years I kept my interests (I was interested in flowers too – not a respected pursuit for a teenage boy) to myself. Fred says "we tended not to advertise ... being birdwatchers ... hid our binoculars under our jackets." This sounds so familiar.

We also share similar losses too. Fred saw his Barn Owls in Blenheim's clock tower which has now been destroyed. I saw my Canadian Barn Owls at Bradley's Marsh, which Fred states was drained for market gardening. Like me, he was also an early visitor and bander at Point Pelee. This was in the days when there

were a thousand birds for every birder, rather than the ratio on my last visit when it was a thousand birders for every bird (at least it seemed that way!). He trots through all the hot birding locales in his travels.

Fred names the many people who influenced his passion for birds. This reads like a who's who of Ontario's birders. He was additionally responsible for inspiring numerous young birders. In his work as a teacher, Fred came into contact with many young people and he used this position wisely. What is odd is that there are two people who are not mentioned – Dennis Rupert, a fixture at Pelee for many years and Harold Axtell, the most respected birder in the Niagara Region.

This was a book for wistful reminiscing when birdwatching went from an obscure obsession practised by a few to a popular pastime of many. Fred started when there were few field guides, while now there are many along with a plethora of DVDs, iPods and iPads, sound recordings and other computer resources. It is a fairly short book and would be an ideal companion on a trip, or at the cottage or simply because it is raining. I think Richard Pope in the Foreword was right when he wrote "more of the old-timers ... (should) write similar reminiscences."

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Birdfinding in British Columbia

By Russell Cannings and Richard Cannings. 2013. Greystone Books Ltd., Suite 201, 343 Railway Street, Vancouver, BC, Canada, V6A 1A4. 466 pages, 29.95 CAD, Paper.

I have been fortunate during my working career to visit BC on many occasions. My meetings took place at all seasons of the year. With the help of local birders I have seen some great birds in the Vancouver and Victoria areas. A couple of summer visits to other parts of BC have added to my list. I made these trips with some scraps of published information, but mostly with the guidance of BC birders.

The Cannings, particularly Richard, are legend in BC. Now Richard and Russell have come out with a bird finding guide to the whole province. They have divided the area into 11 sections. Each section is broken into several zones. So if, like me, you are attending a meeting in Victoria you can read the twenty pages of guidance for that city and surrounding area. There are a number of maps accompanied by detailed instructions to provide the visitor with the best route to follow. This is blended with information on birds likely to be seen. Based on my experience I thought the evalu-

ation the potential birds to found on any given day were realistic. Rarities are included, but they are dealt with in a rational manner (e.g. Spotted Owl – "your chances are extremely slim ...").

I looked up Lighthouse Park, a lovely spot off Marine drive on the north shore of Vancouver. I have visited here several times hoping for a Sooty Grouse. I think the directions and the description of habitat are accurate and appropriate. The bird list includes many that I have found in that locality (but not Sooty Grouse). Over the years I have spent several, combined hours in this park listening to them call, but never seeing them. When I finally saw one at the BC-Alaska border it practically walked over my toes).

The index covers only place names and does not include birds. There is an annotated list of all the special birds (ptarmigan, grouse, tubenoses, Sharp-tailed Sandpiper, alcids, owls and warblers) that mostly offsets this omission. The directions given here can be

specific. For example, for White-headed Woodpecker the authors suggest “McKinny Road between kilometres 9 and 12”. This is in addition to a full description of the site given in the main text.

The book begins with a compact discussion of the BC ecosystems – a useful summary for the visitor. There is a description of the birding year which I found most interesting. Mind you it is a bit galling (as an easterner) to read for February that “the early signs of spring ... Swallows search for newly hatched insects ...”. In Ottawa we are buried in snow, at temperature in the minus 20s, enjoying the “fun” of winter at Winter-

lude. It will be more than a month before the most adventurous swallow swirl around the capital.

There are a number of charming black-and-white drawings of birds. While these are cute, I would have preferred the space to be used for more maps. The maps included are very good, but not all locales have their own area diagram. Indeed there is not a map of BC itself, showing how they have divided the province into eco-regions. The only other quibble I have is I wished they had produced this book twenty years ago.

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned

Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros, AUD Australian Dollars.

ZOOLOGY

Handbook of Larval Amphibians of the United States and Canada. By R. Altig and R. W. McDiarmid. 2013. Cornell University Press, Box 6525, 750 Cascadilla Street, Ithaca, NY, USA, 14851-6525.

* **Wildlife of Australia.** By Iain Campbell and Sam Woods. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 288 pages, 19.95 USD, Paper.

Bees – A Natural History. By C. Toole. 2013. Firefly Books Ltd., 66 Leek Crescent, Richmond Hill, ON, Canada, L4B 1H1. 240 pages, 40.00 CAD, Cloth.

* **Field Guide to the Jewel Beetles of Northeastern North America.** 2012. By S. M. Paiero, M. D. Jackson, A. Jewiss-Gaines, T. Kimoto, B. D. Gill and S. A. Marshall. 2012. Canadian Food Inspection Agency, 1400 Merivale Road, Ottawa, ON, Canada, K1A 0Y9. 411 pages, Free, Paper.

* **The Natural History and Diversity of Diptera.** By Stephen A. Marshall. 2012. Firefly Books Ltd., 66 Leek Crescent, Richmond Hill, ON, Canada, L4B 1H1. 616 pages, 125.00 CAD, Cloth.

Ivory, Horn and Blood – Behind the Elephant and Rhinoceros Poaching Crisis. By R. Orenstein. 2013. Firefly Books Ltd., 66 Leek Crescent, Richmond Hill, ON, Canada, L4B 1H1. 216 pages, 29.95 CAD, Cloth.

* **Frogs of the United States and Canada, 2-vol. set.** By C. Kenneth Dodd Jr. The Johns Hopkins University Press, 2715 North Charles Street, Baltimore, MD, USA, 21218-4363. 1032 pages, 180.00 USD, Cloth.

Mammals of China. Edited by Andrew T. Smith and Yan Xie. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 396 pages, 24.95 USD, Paper.

* **Handbook of the Mammals of the World – Volume 3.** Edited by Russell A. Mittermeier, Anthony B. Rylands, and Don E. Wilson. 2013. Lynx Edicions, Montseny, 8, 08193 Bellaterra, Barcelona, Spain. 952 pages, 207.23 USD, Cloth.

* **Nighthawk!** By Jamie Bastedo. 2013. Red Deer Press, 195 Allstate Parkway, Markham, ON, Canada, L3R 4T8. 245 pages, 12.95 CAD, Paper.

* **Owls.** By Marianne Taylor. 2013. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA, 14850. 224 pages, 35.00 USD, Cloth.

* **Pterosaurs – Natural History, Evolution, Anatomy.** By Mark P. Witton. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 306 pages, 35.00 USD, Cloth.

Sharks – Ancient Predators in a Modern Sea. By S. Jorgensen. 2013. Firefly Books Ltd., 66 Leek Crescent, Richmond Hill, ON, Canada, L4B 1H1. 256 pages, 39.95 CAD, Cloth.

* **The Warbler Guide.** By Tom Stephenson and Scott Whittle. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 560 pages, 29.95 USD, Paper.

Yellowstone Wildlife – The Ecology and Natural History of the Greater Yellowstone Ecosystem. By Paul A. Johnsgard and Thomas D. Mangelsen. 2013. University Press of Colorado, 5589 Arapahoe Ave., Suite 206C, Boulder, CO, USA, 80303. 248 pages, 29.95 USD, Paper. (Electronic book: 23.95 USD, 30 day Electronic book rental: 9.99 USD)

OTHER

* **Antarctica – Global Science from a Frozen Continent.** Edited by David W. H. Walton, British Antarctic Survey, Cambridge. 2013. Cambridge University Press, 32 Avenue of the Americas, New York, NY, USA, 10013-2473. 360 pages, 55.00 USD, Cloth.

The Tangled Bank – An Introduction to Evolution (Second Edition). By C. Zimmer. 2013. Roberts and Company Publishers, 4950 S. Yosemite Street, F2 #197, Greenwood Village, CO, USA, 80111. 426 pages, 80.00 USD, Cloth.

Study Guide to Accompany The Tangled Bank. By Alison Perkins. 2014. Roberts and Company Publishers, 4950 S. Yosemite Street, F2 #197, Greenwood Village, CO, USA, 80111. 240 pages, 25.00 USD, Paper.

* **Birdfinding in British Columbia.** By Richard Cannings and Russell Cannings. 2013. Greystone Books Ltd., Suite 201, 343 Railway Street, Vancouver, BC, Canada, V6A 1A4. 480 pages, 29.95 CAD, Paperback.

For the Birds – Recollections and Rambles. By Fred Helleiner. 2013. Willow Printing and Publishing, Brighton, ON, Canada, K0K 1H0. 71 pages. Obtain from the author at fhelleiner@trentu.ca, 20.00 CAD plus 2.50 CAD for postage and handling or at the lighthouse gift shop at Presqu'île Provincial Park. All profits will be donated to the Friends of Presqu'île 25th Anniversary Environmental Fund.

Wild California. By T. Fitzharris. 2013. Firefly Books Ltd., 66 Leek Crescent, Richmond Hill, ON, Canada, L4B 1H1. 96 pages, 19.95 CAD, Cloth.

The Cambrian Explosion – The Construction of Animal Biodiversity. By D. Erwin and J. Valentine. 2013. Roberts and Company Publishers, 4950 S. Yosemite Street, F2 #197, Greenwood Village, CO, USA, 80111. 600 pages, 60.00 USD, Cloth.

The Analysis of Biological Data (Second Edition). By M. Whitlock and D. Schluter. 2013. Roberts and Company Publishers, 4950 S. Yosemite Street, F2 #197, Greenwood Village, CO, USA, 80111. 704 pages, 99.50 USD, Cloth.

Evolution – Making Sense of Life. By C. Zimmer and D. Emlen. 2013. Roberts and Company Publishers, 4950 S. Yosemite Street, F2 #197, Greenwood Village, CO, USA, 80111. 576 pages, 100.00 USD, Paper.

Experimental Evolution and the Nature of Biodiversity. By R. Kassen. 2013. Roberts and Company Publishers, 4950 S. Yosemite Street, F2 #197, Greenwood Village, CO, USA, 80111. 208 pages, 45.00 USD, Paper.

An Introduction to Population Genetics: Theory and Applications. By Rasmus Nielsen and Montgomery Slatkin. 2013. Sinauer Associates, Inc., Publishers, 23 Plumtree Road, P.O. Box 407, Sunderland, MA, USA, 01375-0407. 298 pages, 62.95 USD, Cloth.

Mathematical Modeling in Systems Biology – An Introduction. By Brian P. Ingalls. 2013. The MIT Press, 55 Hayward Street, Cambridge, MA, USA, 02142-1493. 356 pages, 50.00 USD, Cloth.

* **The North American Journals of Prince Maximilien of Weid.** Edited by S. Witte and M. Gallagher. 2013. University of Oklahoma Press, 1005 Asp Avenue, Norman, OK, USA, 73019 – 0445. 467 pages, 85.00 USD, Cloth.

† **Born Naked.** By Farley Mowat. 2013. Douglas & McIntyre Ltd., 4437 Rondevue Road, P.O. Box 219, Madeira Park, BC, Canada, V0N 2H0. 256 pages, 19.95 CAD, Paper.

† **North Pacific Temperate Rainforests – Ecology and Conservation.** Edited by Gordon Orians and John Schoen. 2013. University of Washington Press, 4333 Brooklyn Avenue NE Seattle, WA, USA, 98195-9570. 416 pages, 60.00 USD, Cloth.

* **Philosophy of a Better World.** By Floris Van Den Berg. 2013. Prometheus Books, 59 John Glenn Drive, Amherst, NY, USA, 14228-2197. 293 pages, 23.00 USD, Paper.

Natural History Museum Book of Animal Records. By M. Carwardine. 2013. Firefly Books Ltd., 66 Leek Crescent, Richmond Hill, ON, Canada, L4B 1H1. 256 pages, 19.95 CAD, Paper.

Walking Wild Shores. By Kevin Winker. 2013. Two Harbors Press, 212 3rd Avenue N, Suite 290, Minneapolis, MN, USA, 55401. 353 pages, 16.95 USD, Paper.

* **Alexander Wilson – The Scot Who Founded American Ornithology.** By Edward H. Burt, Jr. and William E. Davis, Jr. 2013. Belknap Press of Harvard University Press, 79 Garden Street, Cambridge, MA, USA, 02138. 464 pages, 35.00 USD, Cloth.

News and Comment

The Cult of the Red Pine – a Useful Reference for the Over-Afforestation Period of Ontario

PAUL M. CATLING

170 Sanford Ave., Ottawa K2C 0E9, Ontario, Canada; email: catlingp@agr.gc.ca

Catling, Paul M. 2013. The cult of the Red Pine – a useful reference for the over-afforestation period of Ontario. *Canadian Field-Naturalist* 127(2): 198–199.

In 1971 Doug (C.H.D.) Clarke, former chief of Wildlife Branch, Ontario Department of Lands and Forests, wrote a very forward-thinking popular article in the *Ontario Naturalist* magazine about the problems that are faced by native flora and fauna as a result of planting trees (Clarke 1971). I just rediscovered this article, which is an important reference for the over-afforestation period. The “Over-Afforestation Period” of Ontario refers to a time between 1950 and 1970 when extensive planting of conifers in the province led to the widespread loss of native open habitat. In the 1950s, 60s and 70s, there was a compelling interest in tidiness, productivity and erosion control. Open land, especially sandy open land, was viewed as wasteland that had to be converted to pines. Afforestation became widespread. Tree nurseries modernized and were soon producing more pines than there were places to put them. The oak savannas of Pinery Park, on the east shore of Lake Huron, were planted with pines, and so were many open sandy places throughout southern Ontario. Clarke (1971, p. 14) described the impact on wildlife: “I have seen a world of Field Sparrows and Grasshopper Sparrows in Whitechurch and Ganaraska Country disappear.” He provided several examples and noted the loss of duck nesting habitat around the newly created Luther Lake. In eastern Ontario, biodiversity-rich sandy meadows were replaced by Red Pines. Afforestation had gone too far and had claimed many special habitats.

Historically, the Ontario Ministry of Natural Resources (MNR) was responsible for many of the afforestation programs in the province. Through the Agreement Forest Program, which began in 1922, it is said that 147.5 million trees were planted on over 120,000 hectares of land in southern Ontario (ECO 2010). MNR also operated a number of nurseries across the province that provided trees free of charge or at low cost. Between 1905 and 1996, MNR nurseries supplied landowners with 792 million seedlings (ECO 2010). The agreement program was terminated in 1998 and most nurseries were sold or closed by 1999. Despite the withdrawal of MNR, much tree planting continues due to

the desire to protect watersheds, decrease atmospheric carbon, recover natural habitat and provide people with a rewarding pursuit. Planters are included in Stewardship Councils, Conservation Authorities, Trees Ontario, the Ontario Soil and Crop Improvement Association, the Ontario Forestry Association and the Wetland Habitat Fund to name a few. There is also currently a major MNR-supported program called “the 50 million tree program” that intends to plant 50 million trees in Ontario by 2020. Although much tree planting continues, it is now much less of a threat to significant habitats because of: (1) the decline of the major MNR programs that were without sufficient conservation guidelines; and (2) the fact that special habitats are now widely recognized as a result of Species at Risk Legislation and science-based protective organizations such as the Nature Conservancy of Canada. Consequently, there is a trend toward the protection of significant natural features on a local and individual basis. Nevertheless it may still be useful to have a well-advertised and conservation-oriented site selection guideline for tree planting that would guide land managers to be cautious to ensure that the open land intended for planting is not a biodiversity-rich native habitat with rare species that deserves protection.

There is little detailed documentation of the huge and almost unbelievable destruction of special habitat due to afforestation that went on during the Over-afforestation Period. In the Ottawa Valley the decline of the sandhills at Constance Bay (Catling and Kostiuk 2010, Catling et al. 2010) and the recent efforts to restore an open sandy dune in the Pinhey Forest (Catling and Kostiuk 2013) provide examples. Doug Clarke would have been well-satisfied today to see some of this being corrected with the removal of planted pines and restoration of diverse natural ecosystems. Although the impact of the over-afforestation period is not something that we are proud enough of to ever want to document in detail, an overview of this historical, less enlightened period is important in helping to understand the loss of open sandy habitat. Doug Clarke’s reference to it 42 years ago is thus of great interest.

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- Catling, P. M., and B. Kostiuk.** 2013. Community Conservation, SOS-Dunes – they have saved a dune and have a plan! *Trail & Landscape* 47(2): 72–78.
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The Canadian Herpetologist (TCH) 3(1), Spring 2013

The Canadian Herpetologist (TCH) is a publication produced twice each year by the Canadian Association of Herpetologists and the Canadian Amphibian and Reptile Conservation Network.

CONTENTS: Executive Members of Societies — Instructions for Authors — Editorial Notes — Meetings — Feature Articles: Northern Map Turtle – Tortue géographique (*Graptemys geographica*) by *B. Schulte-Hostedde*; Wood Turtle – Tortue des bois (*Glyptemys insculpta*) by *J. Litz* — Field Notes: How did the record hot spring of 2012 affect amphibian calling? by *D. Seburn*; Bringing back childhood memories by *D. O'Connor* — Book Reviews — Thesis Abstracts in Canadian Herpetology: **Banger, N.** M.Sc. 2012. University of Ottawa, Ottawa ON. (Supervisor: Gabriel Blouin-Demers). Consequences of multiple paternity for female fitness in an Ontario population of northern map turtles, *Graptemys geographica*. — **Cuthbertson, R.S.R.** Ph.D. 2012. University of Calgary, Calgary, AB. (Co-supervisors: Jason Anderson and Anthony Russell). Early to Middle Triassic Ichthyopterygians from the Sulphur Mountain Formation of east-central British Columbia, Canada: phylogenetic and evolutionary implications. — **El Balaa, R.** M.Sc. 2012. University of Ottawa, Ottawa ON. (Supervisor: Gabriel Blouin-Demers). Effect of predator diet on predator-induced changes in life history and performance of anuran larvae. — **Fortin, G.** M.Sc. 2012. University of Ottawa, Ottawa, ON. (Supervisor: Gabriel Blouin-Demers). Can landscape composition predict movement patterns and site occupancy by Blanding's turtles? A multiple scale study in Québec, Canada. — **Hynes, S.E.** M.Sc. 2012. University of Calgary, Calgary, AB. (Supervisor: Anthony Russell). Resource partitioning in caudal autotomy and regeneration: Assessing the impact of dietary intake on tail and body growth in the Leopard Gecko (*Eublepharis macularius*). — **Kent, J.** B.Sc. 2013. Laurentian University, Sudbury, ON. (Supervisor: David Lesbarrères). Behavioural analysis: An innovative approach to examining multiple stressor effects in amphibians. — **Klaus, S.** M.Sc. 2012. Queen's Uni-

versity, Kingston, ON. (Supervisor: Stephen Loughheed). Correlates and temporal variation in call phenology of eastern Ontario frogs. — **Lacroix, M.** B.Sc. 2012. University of Ottawa, Ottawa, ON. (Supervisor: Gabriel Blouin-Demers). Do Blanding's turtles in poor quality habitats experience reduced immunocompetence and increased parasitaemia? — **Maddin, H.C.** Ph.D. 2011. University of Calgary, Calgary, AB. (Co-supervisors: Anthony Russell and Jason Anderson). Phylogenetic implications of the morphology and development of the braincase of caecilian amphibians (Gymnophiona). — **Ngar-Yung Leung, M.** M.Sc. 2012. University of Calgary, Calgary, AB. (Supervisor: Anthony Russell). Phylogeography of the Greater Short-Horned Lizard (*Phrynosoma hernandesi*) in Alberta. — **Proulx, C.** B.Sc. 2012. University of Ottawa, Ottawa, ON. (Supervisor: Gabriel Blouin-Demers). Are roads a barrier to movement in Blanding's turtles (*Emydoidea blandingii*)? — **Sanders, S. B.** Sc. 2013. Laurentian University, Sudbury, ON. (Supervisor: Jacqueline Litzgus). The effects of population density on juvenile growth of the painted turtle, *Chrysemys picta*. — **Stewart, K.A.** Ph.D. 2013. Queen's University, Kingston, ON. (Supervisor: Stephen Loughheed). Contact zone dynamics and the evolution of reproductive isolation in a North American treefrog, the spring peeper (*Pseudacris crucifer*). — **Thomasson, V.** M.Sc. 2012. University of Ottawa, Ottawa, ON. (Supervisor: Gabriel Blouin-Demers). Habitat suitability modeling for the eastern hog-nosed snake, *Heterodon platirhinos*, in Ontario. — **Woolley, J.** B.Sc. 2012. Laurentian University, Sudbury, ON. (Supervisor: Jacqueline Litzgus). Increase in biodiversity of reptiles along a latitudinal gradient. — **Xuereb, A.T.J.** M.Sc. 2012. Queen's University, Kingston, ON. (Supervisor: Stephen Loughheed). Characterizing population genetic structure and inferring the influence of landscape features on gene flow in a temperate snake species. — Recent Publications in Canadian Herpetology — News and Announcements — Membership Forms: CARCNET.

Irwin (Ernie) Brodo awarded an Honorary Degree by Carleton University

Canada's top lichenologist received an honorary degree of Doctor of Science from Carleton University on 11 June "in recognition of a distinguished career in lichenology and scientific leadership in the international biosystematics community." Since 1965 he has been at the Canadian Museum of Nature, where he was a Research Lichenologist. A native of New York City, he received a B.S. from City College in New York, an M.S. in biology from Cornell University, and a Ph.D.

in botany from Michigan State University. He has published over 90 research papers, including numerous on British Columbia lichens, and an identification guidebook on the lichens of the Ottawa region. Brodo is a long time member of the Ottawa Field-Naturalists' Club who teaches about lichens. Although he is now technically retired, he continues to work at the Canadian Museum of Nature as Research Lichenologist Emeritus.

Manitoba Government Introduces North America's First Ecosystem Protection Legislation

This past Earth day (22 April), Manitoba became the first jurisdiction in North America to introduce legislation that protects essential habitats for endangered plants and wildlife. The province introduced legislative amendments that create the endangered species and ecosystem act that allow the listing of ecosystems as endangered or threatened and protect them on provincial Crown land. The proposed amendments will also: (1) create a new designation called 'special concern' for species at risk of becoming threatened in Manitoba

and requiring plans to prevent these species from further loss, (2) expand the role of the Endangered Species Advisory Committee to provide recommendations on endangered or threatened ecosystems, (3) add protection orders that empower conservation officials to preemptively stop activities that would endanger habitat and ecosystems, and (4) increase fines and penalties for violations under the legislation. For more information visit www.gov.mb.ca/conservation/tomorrownow greenplan and www.iucn.org.

Dr. J. Roger Bider 1932–2013

The noted wildlife biologist and university professor, Roger Bider, died 29 April 2013 after a long battle with Parkinson's Disease. Dr. Bider spent 35 years at Macdonald College, McGill University, and founded the Ecomuseum in Montreal which he directed for 20 years. He and his many students published extensively on distribution, ecology, behavior and life history of a diverse selection of terrestrial vertebrates in Quebec including rodents, shrews, muskrats, mice, coyotes,

blackbirds, turtles, toads and salamander. Notable study techniques included the use of sand tracks to analyze the movements of small vertebrates. With Sylvie Matte he initiated the *Atlas of amphibians and reptiles of Quebec*, The Ecomuseum and the Atlas continue under the direction of David Rodrigue. A tribute and bibliography will appear in a subsequent issue of *The Canadian Field-Naturalist*.

Upcoming Meetings – I Worldwide Raptor Conference 2013

The 1st international meeting of the Worldwide Raptor conference to be held 21-24 October 2013 in Nahuel Huapi National Park, Bariloche City, Rio Negro province, Argentina. This is a joint meeting between the Raptor Research Foundation, the Neotropical Raptor

Network (The Peregrine Fund) and the World Working Group on Birds of Prey and Owls. Registration is currently open. More information is available at <http://www.raptorresearchfoundation.org/conferences/current-conference>.

Erratum The Canadian Field-Naturalist 127(1)

The first citation at the top of page 79 should be "Russell, R. C., G. F. Ledingham and R. T. Coupland. 1954." not "Russell, R. C., G. F. Ledingham and R. T. Cowpland. 1954."

Editor’s Report for Volume 126 (2012)

Mailing dates for issues in volume 126:

- (1) 3 October 2012
- (2) 4 December 2012
- (3) 25 January 2013
- (4) 23 May 2013

A summary of the distribution of memberships in the Ottawa Field-Naturalists’ Club and subscribers to *The Canadian Field-Naturalist* for 2012 is provided in Table 1. The number of articles and notes in Volume 126 is summarized in Table 2 by topic; totals for book reviews and new titles is given in Table 3; and the distribution of content by page totals per issue is provided in Table 4. Manuscripts (excluding book reviews, notices and reports) submitted to *The Canadian Field-Naturalist* totalled 67 in 2012. Of these, 60 were accepted for publication, and 31 were published in volume 126, along with 18 manuscripts submitted in 2011 and revised in 2012, 1 manuscript submitted in 2010 and revised in 2012, and 1 manuscript submitted in 2009 and revised in 2012. A total of 20 Articles, 25 Notes, 5 Tributes, and 1 Essay were published in 2012.

Trina Rytwinski, Assistant Editor, edited content and acted as an Associate Editor; Elizabeth Morton proofed and edited manuscripts; Wendy Cotie typeset galleys and corrections for page proofs and created pdfs; Roy John, Book Review Editor, requested books for review, selected reviewers, edited submitted reviews, and prepared the new titles listings; Jay Fitzsimmons, Journal Manager, managed financial accounts, issue mailing, and requests for back issues, conducted journal promotion through Twitter and other means, and provided digital content to subscribers. Leslie Cody prepared the Index with proofreading by Frank Pope. Sandra Garland, webmaster of the Ottawa Field Naturalist Club, posted tables of contents, abstracts, and pdfs on the CFN section of the OFNC website. Our Associate Editors managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. The Publication Committee, chaired by Dan Brunton and consisting Paul Catling, Jay Fitzsimmons Sandra Garland, Tony Gaston, Karen McLachlan

Hamilton, Elizabeth Morton, Frank Pope, and Jeff Saarela effectively guided the operation of the journal. I am indebted to our very dedicated and effective team.

The following Associate Editors managed and assessed manuscripts submitted to the CFN: Associate Editors: R. Anderson, Canadian Museum of Nature, Ottawa ON (1); W. B. Ballard (deceased), Texas Tech University, Lubbock, TX (2); C. Callaghan, Luskville QC (9); P. M. Catling, Agriculture and Agri-Food Canada, Ottawa ON (3); F. R. Cook, Emeritus Research Associate, Canadian Museum of Nature, Ottawa ON (6); A. J. Erskine, Sackville NB (7); T. S. Jung, Yukon Government, Whitehorse YT (2); D. F. McAlpine, New Brunswick Museum, St. John NB (3); D. W. Nagorsen, Mammalia Biological Consulting, Victoria BC (6); C. Renaud, Canadian Museum of Nature, Ottawa ON (2); T. Rytwinski, Carleton University, Ottawa ON (5); J. Saarela, Canadian Museum of Nature, Ottawa ON (2).

The following referees reviewed manuscripts submitted to the CFN (number of manuscripts reviewed >1 in parentheses): W. B. Ballard (deceased), Texas Tech University, Lubbock, TX; M. Barclay, University of Calgary, Calgary AB; P. Beier, Northern Arizona University, Flagstaff, AZ; L. Belanger, University of Laval, Quebec QC; D. Boyd, USFWS, Helena, MT; C. D. Bird, Erskine AB; J. Bowman, Ontario Ministry of Natural Resources, Peterborough ON; M. Brigham, University of Regina, Regina SK; D. Brunton, Brunton Consulting, Ottawa ON; R. Brooks (retired) University of Guelph, Guelph ON; J. Burns (retired) Royal Alberta Museum; T. Caro, University of California, Davis CA; P. M. Catling, Agriculture and Agri-Food Canada, Ottawa ON (2); B. Coad, Canadian Museum of Nature, Ottawa ON; A. Desrochers, University of Laval, Quebec QC; T. Diamond, University of New Brunswick Fredericton NB; M. Docker, University of Manitoba, Winnipeg, MB; A.J. Erskine, Sackville NB; B. Fenton, University of Western Ontario, London ON; G. Forbes, University of New Brunswick, Fredericton NB A. J. Gaston, Environment Canada, Ottawa ON; J. Gilhen, Nova Scotia Museum of Natural History, Halifax, NS;

TABLE 1. The 2012 circulation of *The Canadian Field-Naturalist* (2011 in parenthesis). Compiled by Jay Fitzsimmons from mailing list for 126(4).

Subscriber Type	Canada		USA		Other		Total	
Memberships								
Family & Individual	89	(101)	8	(8)	1	(1)	98	(110)
Subscriptions								
Individual	81	(93)	30	(34)	3	(4)	114	(131)
Institutional	122	(120)	164	(179)	27	(23)	313	(322)
Total	292	(314)	202	(221)	31	(28)	525	(563)

TABLE 2. Number of research and observation articles and notes published in *The Canadian Field-Naturalist*, Volume 126, by major field of study.

Subject	Articles	Notes	Total
Mammals	8	12	20
Birds	7	7	14
Amphibians and Reptiles	2	2	4
Fish	2	0	2
Plants	1	3	4
Insects	0	1	1
Total			45

TABLE 3. Number of reviews and new titles published in the Book Review section of *The Canadian Field-Naturalist*, Volume 126, by topic.

	Reviews	New Titles
Zoology	20	43
Botany	2	5
Environment	7	2
Miscellaneous	5	25
Children	2	3
Total	36	78

P. Gregory, University of Victoria, Victoria BC (2); D. Gummer, Parks Canada, Calgary AB; A. Gunn (retired), Government of Northwest Territories, Yellowknife NWT; D. Gustine, USGS, Anchorage AK; T. Herman, Acadia University, Wolfville NS; G. Hilchie, University of Alberta, Edmonton AB; J. Hodson, University of Laval, Quebec, QC; C. Hoodicoff, Associated Engineering, Vernon BC; S. Houston (retired), University of Saskatchewan, Saskatoon, SK; H. Jaqmain, University of Laval, Quebec QC; M. Johnson, Global Wildlife Resources, Bozeman, MT; V. Johnston, Environment Canada, Yellowknife NT; D. Klein, University of Alaska Fairbanks AK; T. Kinley, Parks Canada, Revelstoke BC; E. L. Koen, Trent University, Peterborough, ON; N. Kondla, Genelle, BC; B. Lim, Royal Ontario Museum, Toronto ON; D. F. McAlpine, New Brunswick Museum, St. John NB; J. McRoberts, Texas Tech University, Lubbock, TX; W. Meshaka, State Museum of Pennsylvania, Harrisburg, PA; G. Michener, University of Lethbridge, Lethbridge AB; N. Mundahl, Winona State University, Winona MN; J. O. Murie (retired), University of Alberta, Edmonton AB (3); G. Mowat, British Columbia Ministry of Forests, Lands and Natural Resource Operations, Nelson BC; J. Myers, University of British Columbia, Vancouver BC; D. W. Nagorsen, Mammalia Biological Consulting, Victoria BC; F. Osorio, University of British Columbia, Vancouver BC; B. Patterson, Ontario Ministry of Natural Resources, Peterborough ON; J. Peek, University of Idaho; R. Poulin,

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, Volume 126 (2012), by issue.

	Issue				Total
	1	2	3	4	
Articles	27	59	28	39	153
Notes	33	16	28	20	97
Book Reviews*	18	10	5	13	46
News and Comment, Reports**	3	4	13	4	24
Tributes	7	8	15	0	30
Index	—	—	—	13	13
Advice to Contributors	—	3	3	3	9
Total	88	100	92	92	372

*Includes reviews and new titles listings
** Includes CFN Editor's report, Minutes of the OFNC Annual Business Meeting, and OFNC Awards report.

Royal Saskatchewan Museum, Regina SK; G. Proulx, Alpha Wildlife Research and Management, Sherwood Park AB; M. Pybus, Alberta Environment and Sustainable Resource Development, Edmonton, AB; J. Ray, Wildlife Conservation Society, Toronto ON; R. L. Rausch (deceased), Professor Emeritus, University of Washington, Seattle WA; C. Renaud, Canadian Museum of Nature, Ottawa ON; M. Reudink, Thompson Rivers University, Kamloops, BC; G. Robertson, Environment Canada (2); R. Rosatte, Ontario Ministry of Natural Resources, Peterborough ON; J. Saarela, Canadian Museum of Nature, Ottawa ON; H. Schwantje, British Columbia Ministry of Forests, Lands and Natural Resource Operations, Victoria BC; F. Scott Acadia University, Wolfville NS; D. Seburn, Ottawa ON (2); C. Sheviak, New York State Museum, Albany NY; S. Sobek-Swant, Ryerson University, Toronto ON. Sweanor, Wild Felid Research and Management Association; R. Vallender, Environment Canada, Gatineau, QC; K. Vanderwolf, New Brunswick Museum, St. John NB; R. Virtanen, Oulu University, Oulu Finland; K. Weibe, University of Saskatchewan, Saskatoon, SK; R. Weir, British Columbia Ministry of Environment, Victoria BC; W. Weller, Hydro One, Niagara Falls ON; J. Whitaker Jr., Indiana State University, Terre Haute, Indiana.

The journal was printed at Gilmore Printers, Ottawa. Thanks to Gilmore for overseeing production and printing. I am grateful to President Ann McKenzie and Council of the Ottawa Field-Naturalists Club for their support of the journal. I am also grateful to all of the individual subscribers and authors who encouraged our team as we strive to provide a high-quality scientific journal on natural history. Finally, I thank my family for being patient and supportive throughout many evenings and weekends of working on the journal.

CAROLYN CALLAGHAN
Editor

Book Reviews

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COVER: Adult of the couperi subspecies of the Silvery Blue (*Glaucopsyche lygdamus couperi*) reared from an egg laid on *Astragalus neglectus* (Neglected Milk-Vetch) on 7 June 2012 in an eastern Ontario alvar woodland near Braeside. Photo by Jocelyn Gill. See pages 224–228 in this issue.

Abundance, Distribution, and Species Assemblages of Colonial Waterbirds in the Boreal Region of West-Central Manitoba and East-Central Saskatchewan

SCOTT WILSON

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Central and southern Manitoba contain some of the largest breeding populations of several colonial waterbird species in North America. Despite the value of this region for waterbirds, very little monitoring has been conducted on Lake Winnipeg, Lake Winnipegosis, or Lake Manitoba in the past three decades and little is known about the smaller boreal lakes in adjacent areas to the north. In June 2011, boat surveys were conducted on 11 boreal lakes in west-central Manitoba and east-central Saskatchewan to examine current abundance and distribution of colonial waterbirds in that region. Data from this survey were compared with abundance of colonial waterbirds on Lake Winnipegosis and Lake Manitoba from an aerial survey of these lakes in 2012. Waterbird colonies were located on 7 of the 11 lakes in 2011 and included Double-crested Cormorants (*Phalacrocorax auritus*) (2373 adults, 1134 pairs in 7 colonies), Common Terns (*Sterna hirundo*) (1367 adults, 772 pairs in 29 colonies), Forster's Terns (*Sterna forsteri*) (20 adults, 11 pairs in 1 colony), Herring Gulls (*Larus argentatus*) (876 adults, 568 pairs in 23 colonies), and Ring-billed Gulls (*Larus delawarensis*) (3752 adults, 16 colonies). Common Terns and Herring Gulls appeared to be predominantly breeders and pair abundance for both species increased in a sigmoidal fashion; lakes < 100 km² in area had few breeding pairs. Numbers of Double-crested Cormorants and especially, Ring-billed Gulls, may have included a sizeable non-breeding component. Densities (pairs/lake area) of Common Terns and Herring Gulls were about 2 and 4 times higher, respectively, on these lakes than on Lake Winnipegosis and Lake Manitoba, while Double-crested Cormorant and Ring-billed Gull densities were higher on lakes Winnipegosis and Manitoba. Additional studies of productivity in relation to lake characteristics and connectivity among colonies throughout the region would further our understanding of the importance and sustainability of waterbird populations in this region of the boreal forest.

Key Words: abundance; boreal; colonial waterbird; Common Tern; *Sterna hirundo*; Herring Gull; *Larus argentatus*; Double-crested Cormorant; *Phalacrocorax auritus*; Ring-billed Gull; *Larus delawarensis*; Manitoba; Saskatchewan

Introduction

The North American boreal forest covers a vast region from Alaska through Newfoundland and Labrador (Brandt 2009), and it contains numerous lakes and large rivers that provide potential breeding habitat for colonial waterbirds. The central and southern region of Manitoba, in particular, is a major nesting area for Common Terns (*Sterna hirundo*) and Herring Gulls (*Larus argentatus*), both of which breed primarily within the boreal forest biome, as well as several other species whose breeding range extends more broadly to the south, e.g., Double-crested Cormorant (*Phalacrocorax auritus*), American White Pelican (*Pelecanus erythrorhynchos*), and Caspian Tern (*Hydroprogne caspia*) (Koonz and Rakowski 1985).

To date, there has been almost no work on the waterbird community that uses the many smaller boreal lakes north of approximately 54°N latitude (but see Vermeer 1973; Stelfox and Brewster 1979; Somers *et al.* 2010). From the 1960s through the 1980s, several studies reported on the abundance and distribution of colonial waterbirds on lakes Winnipeg, Winnipegosis, and Manitoba, south of the 54th parallel (Vermeer 1969, 1970; Koonz and Rakowski 1985; Hobson *et al.* 1989). No region-wide monitoring has taken place in central and southern Manitoba in over two decades despite ob-

served declines in the populations of some colonial species further east on the Great Lakes (Morris *et al.* 2010, 2011) and a number of regional threats to waterbirds, including persecution, flooding of colonies due to water level manipulation, and eutrophication of the lakes, which may subsequently impact breeding waterbirds (Hobson *et al.* 1989; Lindenschmidt *et al.* 2012; Schindler *et al.* 2012).

Updated information on the abundance and distribution of colonial waterbirds in Manitoba and Saskatchewan is needed for conservation planning at regional, national, and continental scales. To address this, surveys were conducted in 2011 and 2012 consisting of two components: 1) ground-based surveys in 2011 of several smaller lakes along the southern edge of the Boreal Shield ecozone/the northern edge of the Boreal Plains ecozone, north of 54°N and 2) aerial surveys in 2012 of Lake Winnipeg, Lake Winnipegosis, and Lake Manitoba to monitor all historical colonies and potential new breeding sites (Wilson *et al.* unpublished manuscript). The focus of the 2011 survey, reported on here, was to examine breeding densities and the distribution of colonial waterbirds on smaller boreal lakes north of Lake Winnipegosis. Information on abundance and long-term trends, based on the aerial surveys in 2012, will be presented elsewhere, but I use overall abundance

estimates from lakes Winnipegosis and Manitoba as a basis of comparison for the breeding densities of Double-crested Cormorants, Herring Gulls, Ring-billed Gulls (*Larus delawarensis*), and Common Terns on the smaller boreal lakes.

Methods

Surveys

Surveys were conducted by boat (16 ft Big Lakes model, Lund Boats Inc., Steinbach, Ontario) between 20 and 25 June 2011 (~40 hours of survey effort) on 11 lakes in The Pas–Flin Flon region of west-central Manitoba and east-central Saskatchewan (Figure 1 and Table 1). Lakes included in the survey were Amisk Lake in Saskatchewan and Athapapuskow Lake, Cormorant Lake, First Cranberry Lake, Second Cranberry Lake, Goose Lake, Rocky Lake, Otter Lake, Schist Lake, Simonhouse Lake, and White Lake in Manitoba. Lakes varied in size from 0.6 km² to 360 km². Surveys included the entirety of all lakes, with the exception of

Amisk Lake, where we were unable to survey Missi Bay and the narrow channel to the northwest of Crater Island, representing an estimated 11% of the lake area. Because colonies tend to be on sites surrounded by greater amounts of open water, it is likely that at most only small numbers of breeding birds were missed in this region. For all of the lakes, satellite imagery (Google Image Landsat 2013) was used to identify all potential islands that might contain breeding colonial species. In addition, visual scans of all other islands that were less suitable (e.g., entirely forested islands) were done during surveys of the lake basin.

Digital photographs were taken using a D700 Nikon camera (Nikon Canada Inc., Mississauga, Ontario) and a 400-mm zoom lens, with the magnification adjusted as needed, of the adults at all breeding colonies. Because adults would depart as the boat approached, photographs were taken when the boat was about 75 m away and at approximately 10-m intervals until the boat reached the shore. This was particularly helpful in the

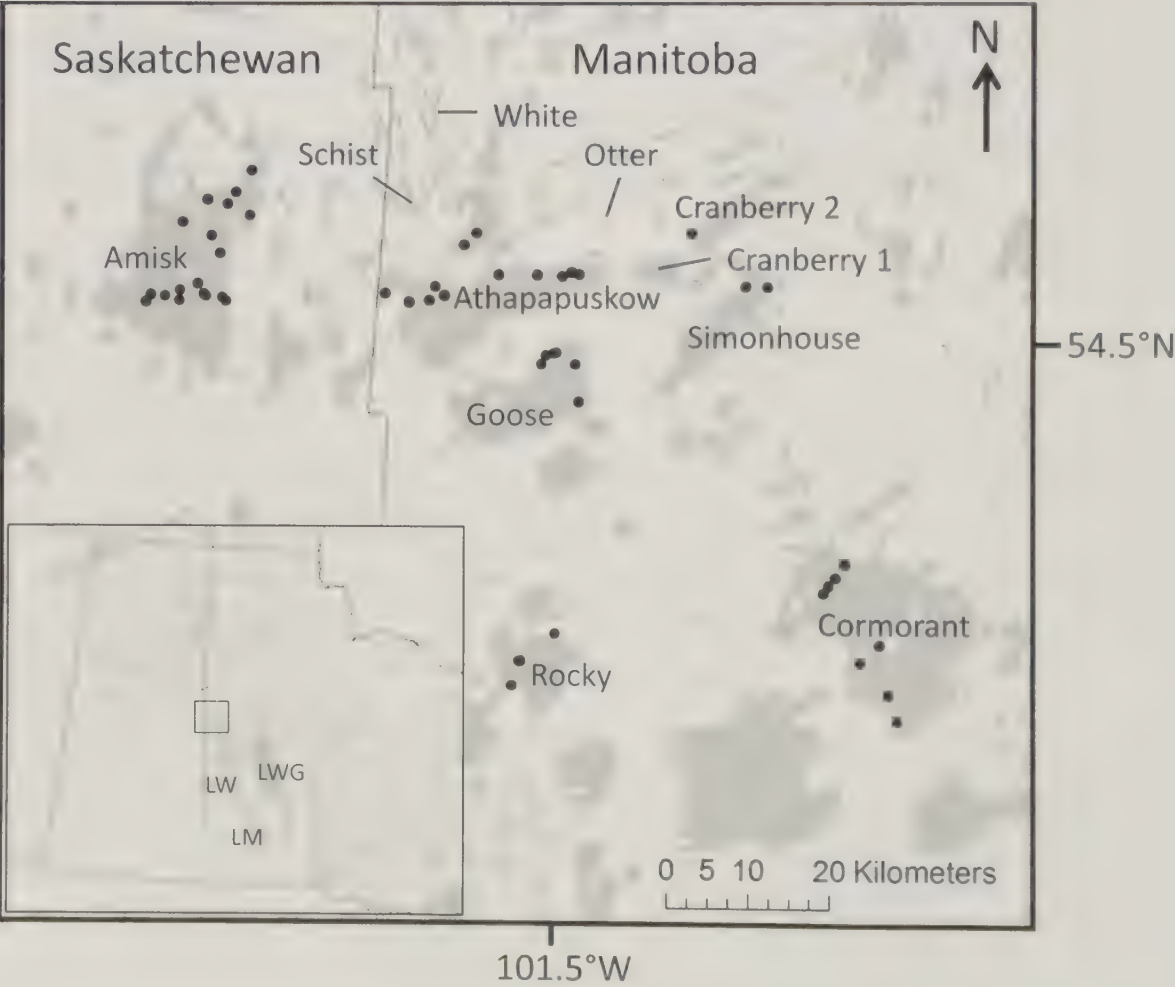


FIGURE 1. Map of the survey area showing boreal lakes that were included in the survey. Circles refer to the locations of waterbird colonies on each lake. Inset map shows Saskatchewan and Manitoba with the square indicating the survey area. The three large lakes surveyed in 2012 are also included; LW = Lake Winnipegosis, LM = Lake Manitoba, LWG = Lake Winnipeg.

TABLE 1. Numbers of adults, estimated breeding pairs, and colonies of four species of colonial waterbirds nesting on lakes in west-central Manitoba and east-central Saskatchewan. Surveys were conducted between 20 and 25 June 2011. Sites refers to locations where at least one species was observed breeding. The adult count for a lake includes individuals at breeding colonies and loafers observed at colonies of other species, but no attempt was made to survey individuals detected while travelling between colonies. Only adult counts are presented for Ring-billed Gulls because of uncertainty in the non-breeding component (see text).

Lake	Area (km ²)	Sites	Double-crested Cormorant			Common Tern			Herring Gull			Ring-billed Gull		
			Adults	Pairs	Colonies	Adults	Pairs	Colonies	Adults	Pairs	Colonies	Adults	Colonies	Colonies
Amisk	360	18	446	165	4	341	186	10	183	120	8	956	6	
Athapapuskow	255	12	0	0	0	294	173	6	291	189	6	275	2	
Cormorant	356	9	0	0	0	423	240	6	183	115	3	660	5	
First Cranberry	21	0	0	0	0	0	0	0	0	0	0	0	0	
Second Cranberry	25	1	0	0	0	26	15	1	0	0	0	0	0	
Goose	136	6	1815	916	1	230	128	3	145	95	3	582	2	
Otter	0.6	0	0	0	0	0	0	0	0	0	0	0	0	
Rocky	111	4	2	0	0	52	31	3	58	39	1	1279	1	
Schist	20	0	0	0	0	0	0	0	0	0	0	0	0	
Simonhouse	85	2	110	53	2	1	0	0	16	10	2	0	0	
White	2	0	0	0	0	0	0	0	0	0	0	0	0	
Total	1371.6	52	2373	1134	7	1367	773	29	876	568	23	3752	16	

case of Common Terns, which often take flight uniformly, and made it possible to capture an entire colony in a single frame. Photographs were taken in raw format and set for the maximum resolution (~34.5 megapixels per image).

Counts

Adult counts were conducted in Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, California) using the digital photographs. Photographs of each colony were first examined to identify the one that best captured the adults and then selected photographs were split into 54 grid cells of equal width. Adults were counted in each grid cell and then summed to produce a total count. At some colonies, multiple photographs were needed and landmarks such as vegetation, rocks, and the position of breeding birds were used to identify sections where photographs overlapped. A drawing tool was then used to exclude sections of one photograph that had been counted in another.

Whenever possible, nest counts were carried out on shore. An active nest was defined as a nest containing eggs or chicks. Nests were counted with a hand-held counter. For the larger colonies, flagging tape was used to section off parts of the colony to keep track of nests that had already been counted.

Estimates of breeding pairs

For sites where nests could be reliably counted, this count was used as the estimate of breeding pairs (one nest equal to one breeding pair). For any sites where it was not possible to go ashore, where chicks had hatched and left the nest, or where there was evidence of recent widespread nesting failure (a case for one Common Tern colony), the count of adults was used to estimate breeding pairs.

Accurate nest counts were possible for 5 of 7 Double-crested Cormorant colonies and 16 of 29 Common Tern colonies. Nest counts were possible for Herring Gulls at only a few sites because chicks had already hatched at most colonies, but the number of chicks observed was recorded and recently used nest structures were noted to confirm a breeding colony.

Breeding pair estimates based on the counts of adults are less certain, because it is not clear what fraction of breeding birds were at the colony during the count. To provide a stronger measure, I determined the ratio of adults to nests at all sites where both could be reliably counted and then applied this estimate to those sites where only adults could be counted. For Double-crested Cormorants, this ratio (scaled to colony size) was 2.19 ± 1.81 (mean \pm SE, $n = 5$), while for Common Terns it was 1.76 ± 0.07 ($n = 16$). The greater error in the ratio for Double-crested Cormorants results in greater uncertainty in the breeding pair estimate.

Based on a small number of Herring Gull colonies at either the egg stage or with chicks still in or beside the nest, the ratio of adult Herring Gulls to nests was 1.63 ± 0.29 ($n = 6$), suggesting ~82% of adult Herring

Gulls were at the colony on average during the incubation stage and early hatchling stages. Colony attendance tends to decrease from incubation through the chick-rearing period, and earlier studies on *Larus* spp. have shown a range of colony attendance of about 60 to 80% (Morris and Black 1980; Pierotti 1987). Surveys also included adults offshore but within the vicinity of the colony (<100 m), and I assumed that 75% of adults were present at colonies during the chick-rearing stages.

Some degree of error is expected in the pair count, and the numbers reported in this manuscript should be treated as a best estimate. The number of adult Ring-billed Gulls was often far higher than the nest count, and Ring-billed Gulls were frequently observed loafing at the colonies of other species (see Results). This potentially suggests a large non-breeding component and I therefore report only the number of adult Ring-billed Gulls without a breeding pair estimate.

Relationship between lake size and breeding abundance

For Common Terns and Herring Gulls, I examined the effects of lake size on breeding abundance by comparing support for a linear, quadratic, and cubic relationship (Kutner *et al.* 2005) between lake area and the estimated number of breeding pairs. Because of the small sample size, I did not consider higher order terms beyond a third-order polynomial. A generalized linear model with a Poisson distribution was used to test this relationship and was performed with program R (R Core Team 2013). Evaluation of support for the three model types was made using Akaike's Information Criterion for small samples (AIC_c), and all models within 2 units of the top model were considered to be supported by the data (Burnham and Anderson 2002). Measures of lake area were made using a Google area mapping tool (Daft Logic 2013). I restricted this analysis to Common Terns and Herring Gulls because Double-crested Cormorants were observed breeding on only three lakes and because of the uncertainty in the estimate of breeding pairs for Ring-billed Gulls.

Comparisons between this region and Lake Winnipegosis and Lake Manitoba were based on estimated densities of each species (pairs or adults per km² of lake area). A detailed description of the methods and results from the aerial survey will be presented elsewhere (Wilson *et al.*, unpublished manuscript), but a brief summary is included here. The survey took place on 13, 15, and 16 June, 2012 and was designed to include all historical and potential new colony sites for island-nesting colonial waterbirds on Lake Winnipeg, Lake Winnipegosis, Lake Manitoba, and the inter-lakes region between the three lakes. Colonies were surveyed by helicopter (13 June) and float plane (15 and 16 June), and high-resolution digital photographs were taken of all locations where any one of the six target colonial species (American White Pelican, Double-crested Cormorant, Ring-billed Gull, Herring Gull, Caspian Tern, and Common Tern) was observed breeding.

Colonial bird counts based on the photographs were conducted in Adobe Photoshop CS5 and included estimates of adults and nest abundance (based on incubating birds); these estimates were then used to estimate the number of breeding pairs at each colony. Calculation of area for Lake Winnipegosis and Lake Manitoba was done using the same method as described above for the small boreal lakes. It was not possible to survey the northeastern portion of Lake Winnipeg in 2012 and I therefore do not include abundance on Lake Winnipeg in the density comparison.

Results

Surveys located a total of 52 sites across the 11 lakes where at least one of the four species was observed breeding (Figure 1). Common Terns and Herring Gulls were breeding on six of the 11 lakes, Ring-billed Gulls on five, and Double-crested Cormorants on three (Table 1). Only two lakes (Amisk Lake and Goose Lake) had breeding activity by all four species, while Schist Lake, First Cranberry Lake, Otter Lake, and White Lake did not have any breeding colonies. Colony characteristics differed among the four species. Common Terns and Herring Gulls were present at a larger number of sites but with fewer pairs per colony: 29 colonies averaging 27 pairs per colony for Common Terns and 23 colonies averaging 25 pairs per colony for Herring Gulls (Table 1). Colony sizes tend to be positively skewed for these species and the median colony sizes were 20 pairs per colony for Common Terns and 17 pairs per colony for Herring Gulls.

The number of breeding pairs was low on small lakes but increased in a sigmoidal pattern with lake area (Figure 2). For both Common Terns and Herring Gulls, a cubic model relating breeding pair abundance to lake area had substantially more support than either the qua-

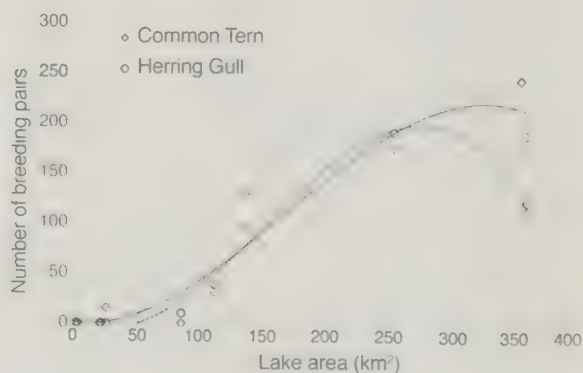


FIGURE 2. Number of breeding pairs in relation to lake area for Common Terns (*Sterna hirundo*) and Herring Gulls (*Larus argentatus*) on boreal lakes in west-central Manitoba and east-central Saskatchewan. Best fit lines for each species are based on a model with a cubic relationship between lake area and number of breeding pairs (solid line = Common Tern, dashed line = Herring Gull).

dratic or the linear model (Common Tern: AIC_c increase = 23.5 units for the quadratic model, 204 units for the linear model; Herring Gull: AIC_c increase = 37.9 units for the quadratic model, 360 units for the linear model). Predictions from the cubic model suggest that the number of Common Terns would increase beyond 10 pairs on lakes exceeding 60 km² and beyond 25 pairs on lakes exceeding 85 km². For Herring Gulls, those same predictions suggest in excess of 10 and 25 pairs on lakes that were greater than 85 km² and 100 km², respectively.

Double-crested Cormorants were breeding at fewer locations than Common Terns and Herring Gulls but had larger average colony sizes (mean = 162 pairs, median = 43 pairs). Eighty-one percent of breeding Double-crested Cormorants were observed at a single colony on Goose Lake with 916 pairs (Table 1). For comparison, the largest Herring Gull colony ($n = 111$ pairs), on Lake Athapapuskow, comprised 19.5% of the Herring Gull pairs on all lakes, while the largest Common Tern colony ($n = 100$ pairs), on Cormorant Lake, contained 12.9% of the Common Tern pairs on all lakes. Because of uncertainty concerning the non-breeding component of the Ring-billed Gull numbers, I only report adult abundance and observed 3752 adults and located 16 breeding colonies. The number of adult Ring-billed Gulls far exceeded nest counts at several colonies, and 11% of adults were observed at sites where only the other species were observed breeding.

Double-crested Cormorants were occasionally observed loafing at the colonies of other species (4.9% of adult observations), while Common Terns and Herring Gulls almost never were (0.004 and 0.006% of adults, respectively). A colony of 11 Forster's Terns (*Sterna forsteri*) was also observed on Cormorant Lake, where they were nesting sympatric to a colony of Common Terns. In this case, the Common Terns were nest-

ing on rocky substrate on the main part of the island, and the Forster's Terns were nesting in a patch of dense emergent vegetation along the periphery. Caspian Terns and American White Pelicans were observed on several lakes, but no breeding colonies were located.

Of the 52 sites, 29 had only one species breeding; of these 29 sites, 27 had either Common Terns or Herring Gulls (Table 2). Both species were typically breeding on small rocky islets, but, despite the large number of colonies for the two, they rarely nested on the same islands. Where Common Terns nested with other species, they were most commonly associated with Ring-billed Gulls; Herring Gulls were more often associated with Double-crested Cormorants. There were three cases where Herring Gulls and Ring-billed Gulls nested on the same island, in which case Ring-billed Gulls tended to nest in dense clusters in the centre of the island and Herring Gulls were scattered around the periphery. There were no sites where all four species were breeding together.

Densities of the four species showed different patterns between the boreal lakes and Lake Winnipegosis and Lake Manitoba. For Common Terns, breeding pair densities on the boreal lakes were about 2.2 times greater than on Lake Winnipegosis and 2.2 times greater than on Lake Manitoba (Table 3). For Herring Gulls, breeding pair densities on the boreal lakes were about 3.4 times greater than on Lake Winnipegosis and 4.1 times greater than on Lake Manitoba (Table 3). Double-crested Cormorants and Ring-billed Gulls showed the opposite pattern. Relative to the boreal lakes, pair densities of Double-crested Cormorants were about 4.6 times greater on Lake Winnipegosis and 3.0 times greater on Lake Manitoba (Table 3). Adult densities for Ring-billed Gulls were 1.5 times greater on Lake Winnipegosis and 1.6 times greater on Lake Manitoba.

TABLE 2. Species assemblages at 52 sites on islands in the boreal region of west-central Manitoba and east-central Saskatchewan. See Table 1 for the total number of sites for each species.

Combination	Cases	Percentage of sites
Double-crested Cormorants only	1	2
Common Terns only	14	27
Herring Gulls only	13	25
Ring-billed Gulls only	1	2
Double-crested Cormorants + Common Terns	0	0
Double-crested Cormorants + Ring-billed Gulls	0	0
Double-crested Cormorants + Herring Gulls	5	10
Common Terns + Herring Gulls	2	4
Common Terns + Ring-billed Gulls ¹	11	21
Herring Gulls + Ring-billed Gulls	3	6
Double-crested Cormorants + Common Terns + Herring Gulls	0	0
Double-crested Cormorants + Common Terns + Ring-billed Gulls	1	2
Common Terns + Herring Gulls + Ring-billed Gulls	1	2
All species	0	0

¹ Includes one colony with Forster's Terns.

TABLE 3. Comparison of adult and breeding pair densities on the boreal lakes in this study in 2011 and on Lake Winnipegosis and Lake Manitoba, surveyed in 2012. Only adult densities are provided for Ring-billed Gulls on the boreal lakes.

Species	Adults/km ² of lake area			Pairs/km ² of lake area		
	Boreal lakes	Lake Winnipegosis	Lake Manitoba	Boreal lakes	Lake Winnipegosis	Lake Manitoba
Double-crested Cormorant	1.73	6.91	3.72	0.83	3.79	2.53
Common Tern	1.00	0.43	0.44	0.56	0.25	0.25
Herring Gull	0.64	0.25	0.19	0.41	0.12	0.10
Ring-billed Gull	2.73	4.13	4.44	—	2.10	2.06

Discussion

Most previous monitoring of colonial waterbirds in Manitoba has focused on breeding populations on lakes Winnipeg, Winnipegosis, and Manitoba (Vermeer 1970, 1973; Koonz and Rakowski 1985; Hobson *et al.* 1989; Koonz 2000). The results reported here indicate that medium-sized lakes in adjacent regions to the north also support notable populations of some species. This is particularly true for Common Terns and Herring Gulls, whose densities were about 2 and 3–4 times higher, respectively, on smaller boreal lakes than on Lake Winnipegosis and Lake Manitoba. Similar levels of abundance were previously reported for these two species on Reindeer Lake, Saskatchewan, to the northwest of the survey area (Stelfox and Brewster 1979).

Densities of Ring-billed Gulls were about 50% higher on Lake Winnipegosis and Lake Manitoba, while densities of Double-crested Cormorants were 3 to 4 times higher on the two large lakes. Double-crested Cormorants are more prevalent in the Boreal Plains ecozone and have only recently expanded their range onto lakes in the Boreal Shield ecozone of Saskatchewan (Doucette *et al.* 2010). It is unknown whether this is an original expansion or the species historically bred further north in the Boreal Shield prior to the population declines of the mid-20th century (Doucette *et al.* 2010). Lake Winnipegosis has one of the largest breeding concentrations of Double-crested Cormorants in North America, with 35 181 and 36 497 pairs in 1987 and 1999, respectively (Hobson *et al.* 1987; Koonz 2000). Numbers appear to have declined since, with only 20 149 pairs observed in 2012 (Wilson *et al.*, unpublished manuscript). Forster’s Tern, recorded breeding in this survey only at Cormorant Lake, is near the northern limit of the breeding range for this species in Manitoba.

Common Terns and Herring Gulls were rarely observed outside breeding colonies, and the adult to nest ratios at colonies were generally less than 2, suggesting that the population of the two species in this region in summer is primarily composed of breeding birds. Single individuals of both species were occasionally seen in flight or on the water away from a colony but only in low numbers. In contrast, large numbers of Ring-billed Gulls were observed at sites where they were not breeding (i.e., the colonies of other species). Even at breeding colonies, the ratio of adult Ring-billed

Gulls to nests was often high: in 5 colonies on Cormorant Lake, we observed 531 adult Ring-billed Gulls but only 40 nests. A lower ratio was found on Amisk Lake, where across 6 colonies 549 adult Ring-billed Gulls and 207 nests were observed. The generally high ratio of birds to nests could have been caused by late breeding. However, this is unlikely, because during the survey even Common Terns, which typically breed later than Ring-billed Gulls (Nisbet 2002; Pollet *et al.* 2012), were at the late incubation stage. Also, the large Ring-billed Gull colony on Rocky Lake contained primarily hatched chicks, and the probability that young would have hatched at some colonies while nesting had not yet been initiated at others seems remote.

There is a chance that some of the adult Ring-billed Gulls observed may have been breeding on nearby lakes that were not included in the survey. Baird (1976) found that Ring-billed Gulls foraged an average of 10.8 km from the breeding colony with a range of 2–31 km. Although the distance from other lakes that might support breeding colonies of Ring-billed Gulls in the study region is considerably greater than 31 km, monitoring of other lakes in the region would help examine this possibility further. Another possibility is that the adult Ring-billed Gulls observed had either forgone breeding in 2011 or had attempted to breed elsewhere and then moved into the study region after their nests failed. The densities of Ring-billed Gulls on the boreal lakes was lower than on Lake Winnipegosis and Lake Manitoba, and this suggests that the boreal lakes are a peripheral breeding area. This might explain the higher ratio of non-breeders to breeders in Ring-billed Gulls than in Common Terns and Herring Gulls.

The number of breeding pairs for Common Terns and Herring Gulls increased in a sigmoidal fashion with lake area, and there were only low numbers of breeding birds on lakes <100 km², suggesting a threshold of suitability. Even three of the smaller lakes in this study, Schist Lake, First Cranberry Lake, and Second Cranberry Lake, are large by comparison to the many other water bodies in the region. Schist Lake and First Cranberry Lake did not have any colonial waterbirds, while Second Cranberry Lake had a single colony of 15 Common Tern pairs. Thus, although a much larger number of small lakes in the 0.1–25 km² range exists in this region, they are unlikely to support populations of colonial waterbirds. Further monitoring across a latitudi-

nal gradient to the north and a greater range of lake sizes would be useful to confirm the relationship between abundance and lake size for different species.

Common Terns and Herring Gulls rarely utilized the same islands for nesting, and Common Terns were more likely to nest in association with Ring-billed Gulls. Studies elsewhere have indicated that Herring Gull predation on Common Tern nests can be substantial and is notably higher at sites where Herring Gulls also breed (O'Connell and Beck 2003). Encroachment of Herring Gulls into colonies of Common Terns has resulted in the latter selecting less favourable nesting sites (O'Connell and Beck 2003) and a general decline in abundance in colonies along the Atlantic coast (Burger and Shisler 1978). Herring Gulls can also inflict heavy losses on Ring-billed Gulls at breeding colonies (Quinn *et al.* 1996).

Studies comparing the effects of Ring-billed Gulls on Common Terns are mixed. Morris and Hunter (1976) reported that interactions were infrequent between the two species in the Great Lakes, and Courtney and Blokpoel (1980) found no significant effects of Ring-billed Gulls on incubation attentiveness or breeding success of Common Terns. However, evidence of predation by Ring-billed Gulls on eggs during panic flights by Common Terns was later reported at Great Lakes colonies (Morris *et al.* 1992). It seems likely that both larid species may be at least occasional predators of Common Tern eggs or chicks, but the segregation between Common Terns and Herring Gulls on boreal lakes in Manitoba suggests that Herring Gulls may be a greater perceived threat, leading to avoidance of the same sites by Common Terns. These surveys were not designed to examine hypotheses underlying interspecific patterns of colony site selection. Further study to provide a better understanding of how all species select breeding sites, as well as the potential implications of fluctuations in the abundance of species for interspecific interactions and breeding success, would be valuable.

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War of the Wasps: Is *Diadegma insulare* or *Microplitis plutellae* a More Effective Parasitoid of the Diamondback Moth, *Plutella xylostella*?

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Parasitism levels by *Diadegma insulare* (Muesebeck) (Hymenoptera: Ichneumonidae) and *Microplitis plutellae* (Haliday) (Hymenoptera: Braconidae) at various densities of their host, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), were assessed. Cages with densities of 10 hosts, 20 hosts, and 40 hosts were set up, with the cage volume (40 500 cm³) and number of wasps (2 females) remaining constant. The host populations were also exposed to the wasps for two different exposure times: 1 day and 3 days. The study showed that *D. insulare* was a better parasitoid overall, achieving a level of parasitism equal to or higher than *M. plutellae* at all densities. *Microplitis plutellae* performed best at a lower host density (76% ± 9% of 10 hosts vs. 43% ± 3% of 40 hosts). *Diadegma insulare* performed similarly at all densities tested (75% ± 5% of 10 hosts, 83% ± 4% of 20 hosts, and 79% ± 6% of 40 hosts). This suggests that *D. insulare* may be the better parasitoid overall and should be applied in severe, large-scale infestations, while *M. plutellae* may be better for small-scale infestations.

Key Words: Diamondback Moth; *Plutella xylostella*; *Microplitis plutellae*; *Diadegma insulare*; parasitoids; biological control

Introduction

Invasive alien species are a large problem both for the environment and for agriculture. The Diamondback Moth (*Plutella xylostella* (L.) (Lepidoptera: Plutellidae)) (Figure 1) is one such species. It is invasive in North America and is thought to be native to Europe or Asia (Harcourt 1954). It is a major pest of crops in the plant family Brassicaceae (which includes canola, cabbage, and broccoli), causing an estimated one billion dollars U.S. in crop damage annually (Sarfaz *et al.* 2005a).



FIGURE 1. Adult Diamondback Moth, *Plutella xylostella*. Photo taken using microscope camera. CNC voucher Diptera 225229. Scale bar = 1 mm. Photo: Jeffery Skevington.

The Diamondback Moth is resistant to many pesticides (Harcourt *et al.* 1986). The scientific community is therefore exploring alternative ways of controlling it, including biological control. Biological control is a method of controlling a pest population (for example, an herbivore) by means of another organism (a parasitoid, predator, or pathogen). If applied properly, biolog-

ical control can provide better control than pesticides. Not only does it avoid the introduction of dangerous chemicals into ecosystems, but it is also more effective because the target pest can never develop a resistance (the biological control agent evolves with the pest, countering pest adaptations with its own).

There are many parasitoid wasps that attack the Diamondback Moth, but two of the most studied are *Diadegma insulare* (Figure 2) and *Microplitis plutellae* (Figure 3). Both of these parasitoid wasps are native to Canada. The wasps attack the Diamondback Moth by implanting an egg into the larval host. The parasitoid inside matures with the host larva and eventually egresses to pupate, killing the host in the process (Sarfaz *et al.* 2005b). The two wasps differ slightly in life cycle: when the Diamondback host reaches the prepupal stage, the *D. insulare* larva consumes it and pupates within the host's already-spun cocoon. *Microplitis plutellae*, however, egresses from the fourth instar larva to find a dry location before pupating (Figure 4).



FIGURE 2. Adult male *Diadegma insulare*. CNC voucher Diptera 225228. Scale bar = 1 mm.



FIGURE 3. Adult female *Microplitis plutellae*. CNC voucher Diptera 225230. Scale bar = 1 mm.



FIGURE 4. *Microplitis plutellae* larva emerging from its host, a fourth instar larva of the Diamondback Moth, *Plutella xylostella*. Scale bar = 1 mm.

Despite the large amount of information collected about these two parasitoid wasps, there are very few data on the effect of host density on the level of parasitism, or the functional response, of the wasps. Some studies (Bolter and Laing 1984) have indicated that there is a difference in functional response, but a comparison of effectiveness of both wasps is lacking. An important way of evaluating the effect of host density on a parasitoid's level of parasitism is by looking at its functional response curve. Most parasitoids have a type II functional response curve, although those with a type III functional response curve tend to be more effective parasitoids (Fernandez-Arhex and Cor-

ley 2002). The functional response curves of *D. insulare* and *M. plutellae* are currently unknown.

The objective of this study was to evaluate the functional response of *M. plutellae* and *D. insulare* to their *P. xylostella* host population, to determine which would be better suited as a biological control agent for Diamondback Moth infestations.

Methods

The experiment tested three levels of density treatments (10, 20, and 40 hosts per cage) crossed with two levels of exposure time treatments (1 day and 3 days). Parasitism by female *Diadegma insulare* and *Microplitis plutellae* wasps was measured separately (see Table 1).

TABLE 1. Number of cages used to produce data for each host density and exposure time treatment, for both *D. insulare* and *M. plutellae*.

Wasp	Exposure time	Host density (No. of hosts per cage)	No. of cages
<i>Microplitis plutellae</i>	1 day	10	5
		20	6
		40	5
	3 days	10	5
		20	6
		40	4
<i>Diadegma insulare</i>	1 day	10	4
		20	4
		40	4
	3 days	10	5
		20	7
		40	4

Parasitoid pupae were collected from a locally-reared culture and placed in a 19 cm × 14 cm × 19 cm cage (fabricated onsite) with a vial containing a 10% solution of sucrose in water. This cage was checked daily so that the approximate age of each of the adult parasitoid wasps to be used in experiments was controlled. The range of acceptable age for wasps was 2–5 days post-egression, to ensure that the wasps were young enough and had been able to mate before being introduced to the host population.

Diamondback Moth larvae (Figure 5) were taken from a culture and placed in a 30 cm × 30 cm × 45 cm cage with a single canola plant. Larvae were placed in each cage at different host densities (in this experiment, host density is specifically the number of hosts, either 10, 20 or 40, per cage), and 10% sucrose vials were placed inside as a source of food for the wasps. After setup, the cages were left in a climate-controlled room (set at 22°C ± 1 Celsius degree and 70% humidity, with 16 hours of light provided by two Sylvania F48T12D/VHO bulbs, 115 W and 6500 K, and two Sylvania Cool Whites F48T12/CW/VHO bulbs, 115 W and 4200 K). This was the beginning of the wasp exposure time,



FIGURE 5. Third instar larva of the Diamondback Moth, *Plutella xylostella*. CNC voucher Diptera 225231. Scale bar = 1 mm.

which lasted for 1 or 3 days, depending on the treatment.

After the wasp exposure time was complete, the parasitoids were removed and the cage was left inside the climate-controlled room for a further 14 days to allow hosts and parasitoids to pupate. The parasitoid and host pupae were removed from the cage and counted. For each replicate, the level of parasitism (based on the number of parasitoid pupae recovered) was recorded as a percentage of the original host population.

Specimens are deposited in the Canadian National Collection of Insects, Arachnids, and Nematodes at Agriculture and Agri-Food Canada in Ottawa, Ontario (CNC) (collection acronyms follow the Registry of Biological Repositories, <http://www.biorepositories.org>).

Results

Parasitism by *Diadegma insulare* remained relatively consistent for both exposure times, sitting at 62% ± 7% for the 1-day exposure time and 75% ± 5% for the 3-day exposure (Figure 6).

Parasitism by *Microplitis plutellae* showed some variation among densities. In the 1-day exposure treatments, the level of parasitism was very low (16% ± 8%

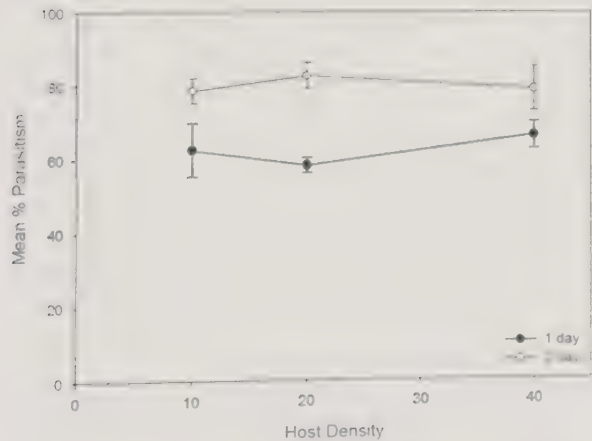


FIGURE 6. Mean (± SE) parasitism of the Diamondback Moth, *Plutella xylostella*, by the larval parasitoid *Diadegma insulare* at different host densities and exposure times.

to 21% ± 3%); the most likely explanation is that the wasps did not have adequate time to parasitize. In the 3-day exposure treatments (where the wasps had more time for parasitism), *M. plutellae* performed optimally at the lowest density, parasitizing 76% ± 9% of the 10 hosts (Figure 7).

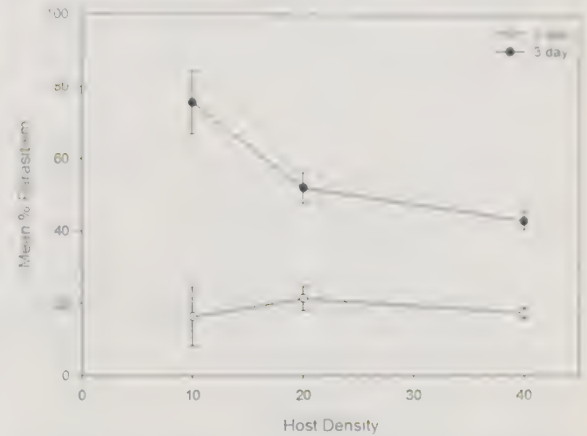


FIGURE 7. Mean (± SE) parasitism of the Diamondback Moth, *Plutella xylostella*, by the larval parasitoid *Microplitis plutellae* at different host densities and exposure times.

In the 1-day exposure treatment, *Diadegma insulare* achieved a much higher level of parasitism than *Microplitis plutellae* at all densities (58% ± 2% to 67% ± 4% for *D. insulare* versus 16% ± 8% to 21% ± 3% for *M. plutellae*) (Figure 8). In the 3-day exposure treatment, *M. plutellae* performed comparably to *D. insulare* at the lowest density, with both wasps achieving similar levels of parasitism (76% ± 9% and 75% ± 5%, respectively). However, as density increased, the parasitism rate for *M. plutellae* dropped to 52% ± 4% (of 20 hosts), and finally to 43% ± 3% (of 40 hosts). The parasitism rate for *D. insulare* remained at approximately the same level (Figure 9).

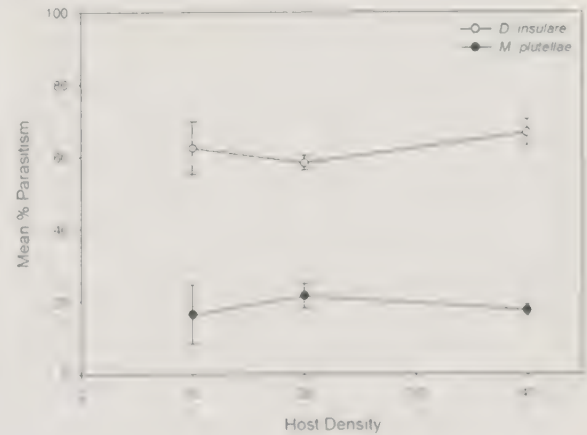


FIGURE 8. Mean (± SE) parasitism of the Diamondback Moth, *Plutella xylostella*, by the larval parasitoids *Diadegma insulare* and *Microplitis plutellae* at the 1-day exposure time at different host densities.

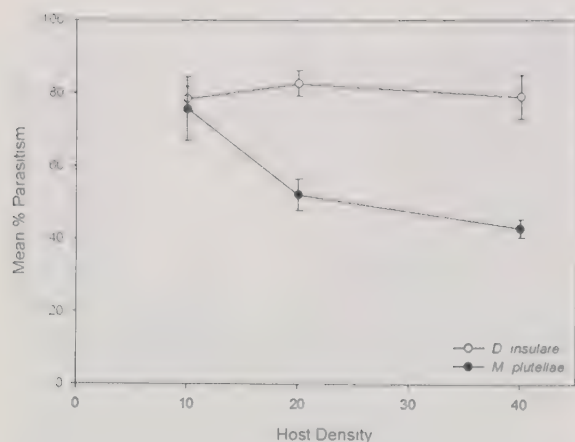


FIGURE 9. Mean (\pm SE) parasitism of the Diamondback Moth, *Plutella xylostella*, by the larval parasitoids *Diadegma insulare* and *Microplitis plutellae* at the 3-day exposure time at different host densities.

When looking at the number of hosts parasitized (as opposed to the percentage of the total host population), a different trend emerges. Both *D. insulare* and *M. plutellae* parasitized a larger number of hosts as host density increased. However, the number of hosts parasitized by *D. insulare* increased at a constant rate, while the number of hosts parasitized by *M. plutellae* increased at a constantly decreasing rate.

Discussion

From a purely functional response standpoint, *Diadegma insulare* seems to be a more effective parasitoid of the Diamondback Moth than *Microplitis plutellae*. *Diadegma insulare* maintained a level of parasitism equal to or higher than that of *M. plutellae* at all densities.

It is possible to identify the functional response curves for *D. insulare* and *M. plutellae* based on the results of this experiment. It appears that *D. insulare* has a type I functional response curve: as the number of available hosts increased, *D. insulare* parasitized a larger number of hosts while maintaining a constant percentage parasitism. It is a somewhat unexpected result, as only one other parasitoid biological control agent (*Eretmocerus eremicus* (Hymenoptera: Aphelinidae)) is known to exhibit a type I functional response (Fernandez-Arhex and Corley 2002). It is important to note that the host densities tested in this experiment were relatively low compared to other experiments (Putnam 1968), and it is likely that the percentage parasitism by *D. insulare* would decrease when the number of available hosts reached a critical mass (as is evident with other type I functional response organisms) (van Alphen and Jervis 1996).

Microplitis plutellae seems to have a type II functional response curve. The number of hosts parasitized by *M. plutellae* rose at a constantly decreasing rate. Thus, as host density increased, a smaller percentage of hosts was parasitized. These are characteristics of

type II and type IV functional responses (van Alphen and Jervis 1996). A type IV response has never been observed in a parasitoid before (Fernandez-Arhex and Corley 2002), so it is more likely that *M. plutellae* has a type II response. Further experimentation (using higher host densities) could provide data to support or refute the inferences made in this paper about the functional response curves of *D. insulare* and *M. plutellae*.

The characterization of the functional responses of *D. insulare* and *M. plutellae* also reveals information about their behaviour. A type I functional response, such as *D. insulare*'s, occurs when a parasitoid's handling time is negligible and egg supply is the only factor that limits parasitism. *M. plutellae* has a type II functional response, suggesting that it takes a relatively long time to find and implant an egg into a host.

Past experiments seem to agree with the results of this experiment. *Microplitis plutellae* has been shown to be more egg-limited than *D. insulare* (Bolter and Laing 1984), producing only 40 eggs per day compared to *D. insulare*'s 50 eggs per day. The studies by Bolter and Laing (1984) have also revealed that the behaviour of the wasps may, in some cases, have a greater impact on their level of parasitism than the number of eggs. In their experiment, *M. plutellae* wasps were able to lay only half of their daily quota of eggs, whereas *D. insulare* wasps were able to lay all of them (when a large enough host population was provided) (Bolter and Laing 1984). This further supports the classification of *M. plutellae* as a parasitoid with a type II functional response—it may be unable to use all of the eggs it produces in a day because it spends too much time interacting with the host.

It is possible that the inferior percentage parasitism of *M. plutellae* is related to superparasitism, a form of parasitism in which the host is attacked more than once by a single species of parasitoid. The percentages superparasitism of *M. plutellae* and *D. insulare* have been compared in previous experiments. Bolter and Laing (1984) suggested that *M. plutellae* is unable to distinguish between a parasitized and a non-parasitized host. However, the functional response experiments of Bolter and Laing (1984) indicated that *D. insulare* and *M. plutellae* maintain an equally low level of superparasitism within a host population. Further research is required to determine the impact that superparasitism may have on the functional response of *M. plutellae*.

There are multiple factors to take into consideration when determining the optimal biological control agent for a pest. In addition to functional response, a parasitoid's adaptability to climate and its impact on non-target species must also be evaluated. Both *D. insulare* and *M. plutellae* are widespread in North America (Krombein *et al.* 1979a,b). *Microplitis plutellae* is found as far north as Ontario and Saskatchewan, as far west as California, and as far east as Virginia. *Diadegma insulare* has an even wider North American distribution.

While both parasitoids are considered native species to Canada and the U.S., the Diamondback Moth is widely believed to have originated in Europe. *Diadegma insulare* is known to attack two other European moths, *Plutella armoraciae* (Busck) (Lepidoptera: Plutellidae) and *Hellula undalis* (Fabricius) (Lepidoptera: Crambidae). Similarly, *M. plutellae* can attack *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), another European pest of Brassicaceae (Krombein *et al.* 1979a). It is likely that these two parasitoids have non-target host species that are native to North America, but these host species are currently unknown.

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Survey Methodology for the Detection of Wood Turtles (*Glyptemys insculpta*)

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Wood Turtles (*Glyptemys insculpta*) are difficult to survey because their use of aquatic and terrestrial environments varies spatio-temporally. Existing survey methodology is highly variable and typically involves searching for Wood Turtles within water and on land 0 to >20 m from the shoreline from spring to autumn. The mobility of Wood Turtles suggests that detection is likely influenced by distance surveyed from water and the amount of vegetation, which varies by season. To determine an ideal survey methodology for the Wood Turtle, we recorded distances from a waterway of 31 radio-tagged turtles at Canadian Forces Base, Gagetown, New Brunswick, in 2003 and 2004. Ordinal logistic regression was used to determine the probability of finding male or female Wood Turtles with increasing distance from water at different times of day or season. Sex and time of day were not significant factors in detecting Wood Turtles. Season was a significant factor, with highest probability (69%) of finding Wood Turtles at a distance of 0–10 m of a waterway up to July 1 (corresponding to pre-nesting and nesting periods), compared to probabilities of <10% for any 10-m distance between 10 m and 50 m from a waterway. After July 1, the highest detection probability (50%) was at distances greater than 50 m from a waterway. We recommend that Wood Turtle surveys for environmental impact assessments and population monitoring be conducted on warm days (i.e., 10–25°C) within 10 m of waterways up to July 1.

Key Words: Wood Turtle; *Glyptemys insculpta*; survey methodology; detection; monitoring; New Brunswick

Wood Turtles (*Glyptemys insculpta*) exist in discontinuous populations in the northeastern United States from Michigan to Maine and south to Virginia (Ernst and Lovich 2009). In Canada, they are found in parts of south-central Ontario and southern Quebec (Desroches and Rodrigue 2004; Committee on the Status of Endangered Wildlife in Canada 2008*), New Brunswick, and Nova Scotia (McAlpine and Gerriets 1999; Gräf *et al.* 2003; Biggar 2008*) and are designated threatened nationally (Committee on the Status of Endangered Wildlife in Canada 2008*), endangered in Ontario (Ontario Wood Turtle Recovery Team 2009*), and vulnerable in Quebec (Équipe de rétablissement des tortues du Québec 2005*). In the United States, they are listed as imperiled or vulnerable in 15 of 17 states (NatureServe 2013*).

Because the Wood Turtle is a listed species, surveys to establish the presence of Wood Turtles are often included in environmental assessments and regulatory permitting for new development projects and road construction (e.g., AMEC 2002*; MacGregor and Elderkin 2003*; Saumure 2007*). Road mortality is a major threat to Wood Turtle viability (Gibbs and Shriver 2002; MacKinnon *et al.* 2005; Steen *et al.* 2006, 2012) because the extensive terrestrial movements of Wood Turtles bring them into contact with roads and exceed the traditional, narrow (e.g., 15 m) riparian buffer protection zones often required in forested and agricultural landscapes (Tingley *et al.* 2009). Accurate information on the presence of Wood Turtles could be applied to mit-

igating development projects and influencing the alignment and design of new roads (Langen *et al.* 2012).

Survey methodology for turtles is often based on counts of basking or road-killed animals or capture in specially designed traps (Gordon and MacCulloch 1980; Lindeman 1999; Haxton 2000; Summer and Mansfield-Jones 2008). Unless they are nesting, semi-aquatic turtle species, such as Painted Turtles (*Chrysemys picta*), Northern Map Turtles (*Graptemys geographica*), and Snapping Turtles (*Chelydra serpentina*), generally remain in or next to a waterway (Gamble and Simons 2004; Carrière and Blouin-Demers 2010; Patterson *et al.* 2012; Steen *et al.* 2012), resulting in a more defined and restricted survey area and increased confidence that detection is likely within a set distance from water.

Species that are more terrestrial, such as the Wood Turtle and the Bog Turtle (*Glyptemys muhlenbergii*), are more difficult to survey because a large proportion of the population does not bask near water and they travel unpredictable distances from water (Carter *et al.* 2000; Morrow *et al.* 2001). Wood Turtles, for example, have been recorded 300–600 m from waterways in seven studies (Tingley *et al.* 2009), and, in one study, 32% of relocations were >50 m from water (Arvisais *et al.* 2002).

Difficulties in detecting the often camouflaged Wood Turtle are compounded by the spatio-temporal variability in the species' use of water and terrestrial habitat. Within a 24-hour period, basking Wood Turtles will return to water as the ambient temperature drops, and

they may not leave the water until later the following morning (Harding and Bloomer 1979; Daigle 1997; Arvisais *et al.* 2002).

Use of water also varies by season and sex; Wood Turtles often remain near waterways during the spring and autumn, but move further from water during mid-summer (Farrell and Graham 1991; Kaufmann 1992; Arvisais *et al.* 2002, 2004). Female Wood Turtles are known to move greater distances than males and through different habitats, presumably to find an appropriate nesting location and for post-nesting foraging (Obbard and Brooks 1980; Gibbs and Shriver 2002; Steen *et al.* 2006; Walde *et al.* 2007). For example, 95% of male locations in an agri-forest site in Nova Scotia were within 43 m of a waterway but only 65% of female locations were within 43 m of a waterway (Tingley *et al.* 2009). Overall, the likelihood of an individual being detected in a survey could vary greatly by time of day, season, and sex.

Survey methodologies for Wood Turtles are not standardized. Most researchers capture Wood Turtles in spring during a short period of three weeks characterized by warm ambient temperatures prior to the “green-up” of vegetation (e.g., Arvisais *et al.* 2004; Walde *et al.* 2007). However, population surveys and monitoring are conducted by numerous methods and over different seasons.

Throughout its range, surveys for the Wood Turtle have been conducted during spring (Quinn and Tate 1991; Saumure and Bider 1998; Arvisais *et al.* 2002; Dubois *et al.* 2008), autumn (Compton *et al.* 2002; Greaves and Litzgus 2007), or multiple seasons (Jones *et al.* 2012). The width of the survey area varies. Some surveys begin in water or from the shoreline and extend 10, 20, or 30 m inland (Saumure and Bider 1998; Arvisais *et al.* 2002; Hunsinger 2002*; Committee on the Status of Endangered Wildlife in Canada 2008*; Jones *et al.* 2012*; M. Pulsifer, Nova Scotia Department of Natural Resources, personal communication, 2012). The United States Forest Service recommends a survey using three people, one person on either side of the waterway surveying the banks, and one on foot, or possibly a canoe, in the centre of the river (Bowen and Gillingham 2004*). A standardized survey protocol being developed for the Wood Turtle in New England requires one or two observers with non-overlapping tracks searching within 10 m of a shoreline 1 km in length for 2 hours, three times within a three-week period (Jones *et al.* 2012*). The number of surveyors over an area 10–15 m from a stream in Quebec varied between one and ten people (Arvisais *et al.* 2002), although most surveys are now conducted by a person on each shore and one in a canoe (Daigle 1996*).

The lack of standardized survey methods raises concern about the efficacy of environmental impact surveys, long-term monitoring, and comparisons among regions. The value of environmental impact assessments is predicated on proper survey techniques that

can detect rare species; failure to detect is a concern because mitigation or avoidance practices typically are not applied if the presence of rare species is not confirmed.

Given the mobility of Wood Turtles, we predicted that survey distance from the waterway would strongly influence detection probability. We also predicted that season would be an important factor in detection because vegetation growth (and the potential concealment of Wood Turtles) increases from spring to autumn.

In this paper, we use independent locations from a population of radio-tagged Wood Turtles to determine the probability of detecting a Wood Turtle under different conditions, separate from observer bias associated with vegetation or search effort. Our intent is to establish the importance of standardizing methodology for surveying Wood Turtle populations.

Methods

Study area

A total of 31 Wood Turtles was captured and marked in order to assess movement in three waterways on Canadian Forces Base Gagetown, New Brunswick (45°40'N, 66°20'W), during the spring and autumn seasons in 2003 and 2004 (May 1–October 1). We marked 27 adults (14 males and 13 females) and 4 juvenile Wood Turtles for identification using a shell notching system (Cagle 1939) and radio-telemetry devices (Model AI-2F juveniles; 12 g juveniles; 30 g adults; Holohil Systems Ltd., Carp, Ontario) on the right posterior scute (University of New Brunswick Animal Care Committee permit 04017).

Adults were defined as having >14 annuli on carapacial scutes and secondary sexual characters (Lovich *et al.* 1990; Farrell and Graham 1991; Walde *et al.* 2003). Our results pertain to adults and large juveniles (i.e., >100 mm carapace length (CL)). Carapace length in the adult sample ranged from 165 to 241 mm. One Wood Turtle had a carapace length of 164 mm but was considered to be a juvenile based on the number of rings (10) and lack of secondary sexual characteristics. Our sample of juvenile Wood Turtles was <10 years old with a carapace length range of 100–164 mm.

Initial captures of Wood Turtles were made using a two-person visual survey within 10 m of a waterway. Although our marked population was captured near shore, we believe it was representative of the larger population because literature indicates that there is no evidence of a separate Wood Turtle population beyond 10 m; individual Wood Turtles frequently move near and far from waterways and captures within 10 m would contain turtles using habitat beyond 10 m (Arvisais *et al.* 2002, Walde *et al.* 2007, Tingley *et al.* 2009). Wood Turtles were located a minimum of once per week between 0800 and 1800. A subset of six adult Wood Turtles (three males and three females) was tracked hourly for a 24-hour period up to and after

July 1 in 2004, as part of a project on influence of temperature on habitat use. Air and water temperature were recorded hourly.

The survey period up to July 1 (early season: May 1–July 1; $n = 133$ relocations) corresponds to the pre-nesting and nesting period, and the survey period after July 1 (late season: July 2–October 1; $n = 214$ relocations) corresponds to the post-nesting period known to influence Wood Turtle movement and habitat use (Arvisais *et al.* 2002; Compton *et al.* 2002). Nesting Wood Turtles were removed from analyses. Distance to water was measured using measuring tape; when Wood Turtles were further from water, GPS (Garmin Model 72) and GIS-based mapping were used. Data on distance from water were categorized as within water, in one of five 10-m increments to 50 m (0–10, 10.1–20, 20.1–30, 30.1–40, 40.1–50 m), and beyond 50 m. We divided days into five 2-hour segments beginning at 0800 and ending at 1800: 0800–10:00 (morning), 1001–1200 (late morning), 1201–1400 (early afternoon), 1401–1600 (late afternoon), and 1601–1800 (evening).

Statistical analyses

We conducted ordinal logistic regression using Minitab 16 (Minitab 16 Statistical Software 2010*) to determine the expected proportion of sightings at a certain distance compared to all other distances, and depending on three parameters (sex, season, and time of day). Distance was treated as the response, and each parameter was tested using separate ordinal logistic regressions. Estimated effects from the ordinal logistic regression represent the probability of finding a Wood Turtle within a specific parameter at a specific distance from shore compared to finding a Wood Turtle at all other distances. For example, using sex as a parameter and for male turtles specifically

$$\ln \left(\frac{\text{Probability (sighting a male turtle at certain distance or closer)}}{\text{Probability (sighting a male turtle at any other distance)}} \right)$$

We tested the significance of the parameters (sex, season, and time of day) against a χ^2 distribution to determine whether any parameter had a significant effect on the distance from water when Wood Turtles were relocated. We used the program R version 2.13.1 (R Development Core Team 2011*) to verify the results and created a contingency table using counts of individuals, coding them by sex, season, time of day, and distance.

Results

Sex ($P = 0.67$) (Figure 1) and time of day ($P = 0.99$) (Figure 2) were insignificant in determining the probability of detecting Wood Turtles with increasing distance from the water. However, season was a significant factor ($P = 0.00$) (Figure 3), with the highest probability of detection up to July 1 (69%) occurring within 10 m of a waterway (Figure 3, Table 1). The probability of finding Wood Turtles up to July 1 remained between

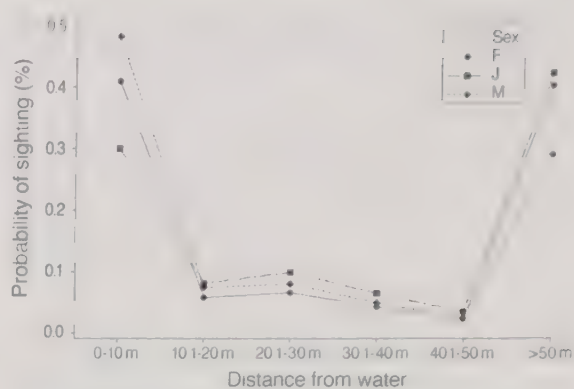


FIGURE 1. Probability of adult male, adult female, and juvenile Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, May 1–October 1, 2003 and 2004.

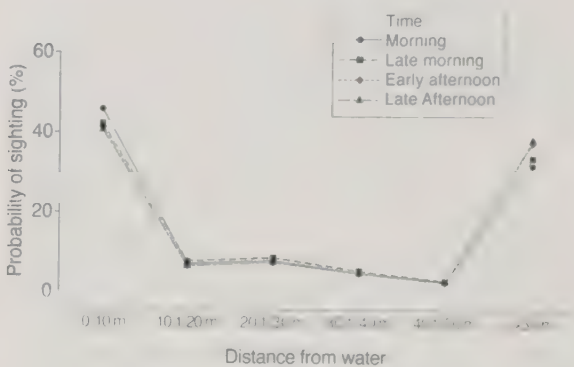


FIGURE 2. Probability of Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, during different time periods of the day, May 1–October 1, 2003 and 2004. Early morning = 0800–10:00, late morning = 1001–1200, early afternoon = 1201–1400, late afternoon = 1401–1600.

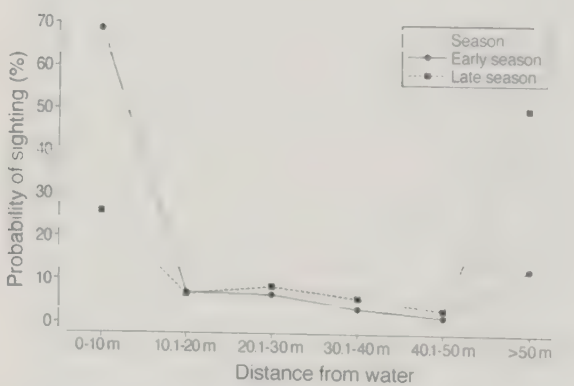


FIGURE 3. Probability of Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, in early (up to July 1) and late (after July 1) seasons of 2003 and 2004.

TABLE 1. Percent probability of Wood Turtles (*Glyptemys insculpta*) being detected along waterways in Canadian Forces Base Gagetown, New Brunswick, Canada, up to July 1 and after July 1, 2003 and 2004.

	Up to July 1	After July 1
0–10 m	68.6	25.9
10.1–20 m	7.2	6.7
20.1–30 m	6.6	8.5
30.1–40 m	3.4	5.8
40.1–50 m	1.6	3.2
>50 m	12.6	49.9

2% and 7% for any 10-m distance from a waterway between 10 m and 50 m, and the probability increased to 12.6% beyond 50 m (Figure 3, Table 1). After July 1, the highest probability of sightings (50%) occurred at distances greater than 50 m from a waterway (Figure 3, Table 1). The probability of a Wood Turtle being present within 10 and 50 m of a waterway remained between 3% and 9%, and it increased to 26% for areas less than 10 m from a waterway (Figure 1). A total of 13.3% of all Wood Turtles was located in water. The longest distance a Wood Turtle was recorded from a waterway or known water body was 574 m.

Although sex had no significant effect on the probability of detecting Wood Turtles, there was a general trend for females to be further than males from waterways after July 1 (Figure 4). Time was also statistically insignificant, although, in the early season, there is a suggestion of increasing distance moved from waterway during the day (Figure 5).

Movements by the subsample of six Wood Turtles monitored for two 24-hour periods suggested that temperature affected the daily distance that the Wood Turtles moved from water. The average night-time (1700–0500) water temperature was 5.2 Celsius degrees (SD 0.9) warmer than the average nighttime air temperature up to July 1 (7.8°C, SD 1.1). At night, all six Wood Turtles moved to water, with three staying in small stagnant pools 15 m from a waterway and three Wood Turtles spending up to 6 inactive hours in the main river (12 m in width).

During this period up to July 1, when the water temperature is warmer than the air temperature, the Wood Turtles were significantly closer to water at night (average distance 7.0 m, SD 3.6) than they were in the daytime (14.6 m, SD 4.7; *t* test; *P* = 0.01). After July 1, the average nighttime air temperature (15.0°C, SD 0.8) was 2.4 Celsius degrees (SD 0.9) colder than the average water temperature; during this period, five of six Wood Turtles did not return to water at night. The average distance from water was >100 m further than in the period up to July 1 and was similar between daytime (136 m, SD 21.8) and nighttime (125 m, SD 32.4; *P* = 0.5).

The onset of daily movement by the subsample of Wood Turtles was highly variable, with earliest activity at 0630 and no movement recorded after 2030.

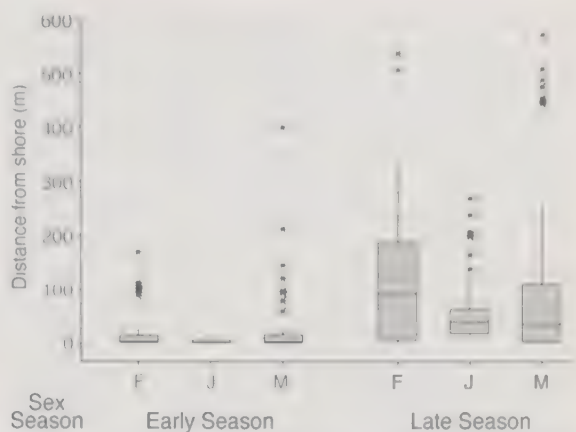


FIGURE 4. Distance from waterway of radio-tagged adult female (F), juvenile (J), and adult male (M) Wood Turtles (*Glyptemys insculpta*) in Canadian Forces Base Gagetown, New Brunswick, Canada, in early (up to July 1) and late (after July 1) seasons, 2003 and 2004. Boxes represent 50% of data, with median represented by centre line. Vertical line is the remaining upper and lower 25% of data, and asterisks represent outliers.

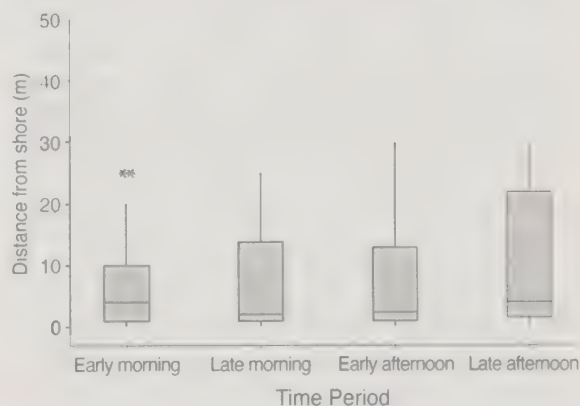


FIGURE 5. Distance from waterway by time of day of radio-tagged Wood Turtles (*Glyptemys insculpta*) in the 2003 and 2004 active season, Canadian Forces Base Gagetown, New Brunswick, Canada. Early morning = 0800–10:00, late morning = 1001–1200, early afternoon = 1201–1400, late afternoon = 1401–1600. Boxes represent 50% of data, with median represented by centre line. Vertical line is the remaining upper and lower 25% of data, and asterisks represent outliers.

Average onset of movement was mid-day (1130, SD 61 minutes). Average straight-line distance moved in 2-hour periods by males was 15.1 m (SD 5.4) up to July 1 and 19.4 m (SD 6.3) after July 1, and average straight-line distance moved by females was 1.25 m (SD 0.4) up to July 1 and 8.8 m (SD 3.1) after July 1. Basking occurred between 0845 and 1445. When temperatures exceeded 25°C, Wood Turtles typically moved to sheltered areas after 1400.

Discussion

The main variables that influenced the probability of detecting a Wood Turtle in this study were distance

from water and season. Wood Turtles were distributed from 0 to over 300 m from waterways, but most were near water; 74% of radio-tagged Wood Turtles were found in a zone from inside the waterway to 10 m inland, and 48% were between the shoreline and 10 m inland.

Our results are similar to those recorded elsewhere. In an agricultural landscape in Nova Scotia, approximately 40% of male and female Wood Turtle relocations were within 20 m of water, and many were within a shrub riparian buffer strip 10 m wide (Tingley *et al.* 2009). In Pennsylvania, the average distance of relocated Wood Turtles from a waterway was 16 m (range 0–250 m) (Ernst 2011).

It is apparent that a survey conducted close to the shoreline has the potential to successfully locate Wood Turtles. However, a near-shore survey likely would be biased towards detecting males. The recorded width of habitat containing 95% of marked Wood Turtles is 235 m for females compared to 43 for males (Tingley *et al.* 2009) and 188 m for females compared to 61 for males (Tuttle and Carroll 2003). Females move farther from shore than males and spend less time in water than males (Gibbs and Shriver 2002; Tuttle and Carroll 2003; Steen *et al.* 2006; Walde *et al.* 2007). Much of the extended female movement relates to nesting behaviour, but even post-nesting females may reside further from water (Tuttle and Carroll 2003; this study).

The large numbers of Wood Turtles regularly occurring beyond 10 m represents valuable data, and it is necessary to survey at greater distances from water if the goal is to document most of the population or most females. In Nova Scotia, 60% of relocated males were between 20 and 60 m from water (Tingley *et al.* 2009). Surveys that would cover 95% of known movements may require survey widths of 150–235 m (Arvaisais *et al.* 2002; Tingley *et al.* 2009). In the current study, detection probability up to July 1 for both sexes combined was highest at 0–50 m from the waterway. However, extending the distance surveyed from the shoreline affects staff and budget issues, which in turn affect survey frequency and the ability to perform long-term monitoring. Our surveys required two people approximately 1 hour to cover 1 km of shoreline 0–10 m from the waterway; the extra 40 m in width required for a late-season survey would require 5 hours/km, or 10 person-hours.

Close proximity to water was most prevalent up to July 1, as has been recorded in other studies (e.g., Carroll and Ehrenfeld 1978; Harding and Bloomer 1979; Arvaisais *et al.* 2002). Wood Turtles typically hibernate in rivers and streams (Greaves and Litzgus 2007, 2008), and movement is minimal in the spring when air temperature is below 3°C or water temperature is below 6°C (Ernst 1986). The limited movement may also be due to mating behaviour and a proportion of females staying near nesting sites (Harding and Bloomer 1979;

Bowen and Gillingham 2004*; Walde *et al.* 2007; Ernst and Lovich 2009).

Similar to other studies (i.e., Harding and Bloomer 1979; Committee on the Status of Endangered Wildlife in Canada 2008*), nesting sites in this study were made in June on gravel sandbars in, and adjacent to, meandering waterways (Graham Forbes, unpublished data). In later summer, Wood Turtles move further from waterways, likely in search of food and facilitated by warmer nighttime air temperatures (Quinn and Tate 1991; Kaufmann 1992; Arvaisais *et al.* 2002). In this study, Wood Turtles were less likely to occur near water after July 1 (i.e., 27% within water to 10 m from the waterway, and 22% from 0 to 10 m), and a survey after July 1 would need to cover habitat 0 to 50 m from the waterway in order to achieve a 50% probability of detection, compared to a 69% probability when conducting a survey of habitat 0 to 10 m up to July 1.

Time of day was not a strong predictor of detection in this study, but results from the subsample of Wood Turtles showed enough temporal movement to suggest that time of day will affect detection. Wood Turtles often rest in waterways at night and move inland to forage during the day (Kaufmann 1992; Arvaisais *et al.* 2002; this study). Surveys conducted near water in the morning would therefore detect Wood Turtles leaving the water and basking near shore. Surveys conducted only later in the day should extend further inland than 10 m from the water.

Wood Turtles are more likely to be out of water and active on land during warm conditions (Ernst 1986; Farrell and Graham 1991). Overcast days will limit the number of basking Wood Turtles, and this may affect the number of Wood Turtle sightings. Wood Turtles will estivate when ambient temperature exceeds 25°C (Ross *et al.* 1991; this study) and thus are less likely to be detected if they are not moving or are concealed under protective cover.

Individual Wood Turtles with a carapace length of less than 100 mm were not radio-tagged; therefore, our results relate to detection of older juveniles and adults (Tuttle and Carroll 2005a). Hatchling Wood Turtles have different environmental cues, movement patterns, and habitat use than adults (Tuttle and Carroll 2005b; Castellano *et al.* 2008), and our results do not apply to hatchlings or young juveniles.

The probability of detection in this study does not directly account for the influence of vegetation, which would be an issue later in the season. In the study site, small areas (e.g., <1 m²) of vegetation-free ground typically would be used by basking Wood Turtles, but these bare spots became harder to detect as grass grew higher. Sandbars and adjacent fields became heavily vegetated by grass >1 m high, and by the end of June it was no longer possible to detect Wood Turtles efficiently. Although not tested in our study, trained dogs have proven successful in locating Desert Tortoises (*Gopherus agassizii*) and Eastern Box Turtles (*Ter-*

rapene carolina) concealed in vegetation (Nussear *et al.* 2008; Kapfer *et al.* 2012). If trained dogs were widely used to detect Wood Turtles, this could greatly increase the period of survey. Initial efforts using dogs to find Wood Turtles in Nova Scotia suggest the method is promising (S. Mockford, personal communication, 2013).

Escape behaviour would also influence detection. Deep vegetation surrounding a stream will conceal an immobile species of small turtle possessing a dark, mud-covered carapace. But turtles also may avoid detection by moving; a Wood Turtle can detect an approaching predator from several metres away, giving it time to retreat to the water or hide further under the vegetation (Peterson 1966). Whether a turtle hides or flees may be related to habitat type, because Saumure and Bider (1998) found that Wood Turtles in forest sites escaped to waterways and those in agri-forest sites remained still. Wood Turtles are one of the faster species of turtle, with speeds reaching 0.32 km/h (Woods 1945). This study did not assess these variables, and it would be informative to develop correction factors for distance sampling methods, as has been done for the Desert Tortoise (Freilich *et al.* 2000; Nussear and Tracy 2007).

In conclusion, expectations of equal probability of detecting a Wood Turtle or most members of a population of Wood Turtles within a narrow strip in any month or time of day are not warranted. If the goal of a survey is to establish the presence of this species at risk, then we recommend that surveys be conducted before July, prior to vegetation growth, and when ambient air temperature exceeds the temperature of the water (in our area this was when ambient air temperature exceeded 10°C). Increasing the survey width from 10 m to 20 m from the waterway gained only a 7% increase in probability of detection, and the extra effort beyond a survey from 0–10 m does not seem justified. Although 13% of our relocated Wood Turtles were in water, we suspect that detection in water, due to varying depth and turbidity, would be highly variable. Surveys in water are not recommended unless the entire survey area is composed of shallow, narrow, and clear streams (e.g., Saumure and Bider 1998). A larger number of surveyors will yield a better population estimate; however, the numbers must be kept reasonable to ensure a similar number of surveyors can be maintained each year in any long-term monitoring project.

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An Alvar Race of the *couperi* Subspecies of the Silvery Blue (*Glaucopsyche lygdamus couperi*) in Southeastern Ontario?

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The *couperi* subspecies of the Silvery Blue (*Glaucopsyche lygdamus couperi*) has expanded its range southward in north-eastern North America using introduced legumes and open anthropogenic habitats. The discovery of a population of the Silvery Blue (*Glaucopsyche lygdamus*) in an eastern Ontario alvar woodland in 2011 suggests that the Silvery Blue may have been long established (although restricted) in southern Ontario. Three larvae from this population were reared from eggs deposited on native Neglected Milk-Vetch (*Astragalus neglectus*) by free-flying females in 2012. The three larvae, pupae, and single reared adult, as well as other adults from the alvar woodland, are described and compared with specimens associated with open anthropogenic habitat and introduced legumes. The alvar woodland specimens were closer to the northern Ontario subsp. *couperi* than to the subsp. *lygdamus* of the eastern United States. Although the alvar woodland larvae were darker green than subsp. *couperi* and the spots on the adults were on average larger than in subsp. *couperi*, the alvar woodland Silvery Blues could not be definitively distinguished from subsp. *couperi*, including specimens from northern Ontario and those from southern Ontario associated with open habitats. Nevertheless, there is a possibility that the alvar woodland population of the Silvery Blue dates from early postglacial times and represents a distinct race separate from the Silvery Blue of open habitats.

Key Words: Silvery Blue; *Glaucopsyche lygdamus*; *Glaucopsyche lygdamus couperi*; *Glaucopsyche lygdamus lygdamus*; alvar; Ottawa valley; Neglected Milk-Vetch; *Astragalus neglectus*; host plant; food plant; distribution; ecology; subspecies; southern Ontario

Most of the north and northeast of North America south of the Arctic and north and west of the prairie region is thought to be occupied by the northern subspecies *couperi* Grote 1873 of the Silvery Blue (*Glaucopsyche lygdamus* Doubleday 1841) butterfly (Lepidoptera: Lycaenidae). It is pale silvery blue above with a greyish underside, and it has relatively small spots on the underside of the hind wing (Howe 1975; Scott 1986) (see Dirig and Cryan (1991) for more details).

At the present time in southern Ontario, these butterflies are usually associated with open anthropogenic habitats and introduced legumes (Layberry *et al.* 1982, 1998). They are believed to have moved into southern Ontario relatively recently (Dirig and Cryan 1991; Layberry *et al.*, *in press*) in response to the recent and now widespread availability of introduced legume food plants (native legumes were likely uncommon and localized in pre-settlement times).

In June 2011, seven Silvery Blues were captured in Malaise traps as part of a pollinator study in an alvar woodland near Braeside, Ontario, north of Arnprior in the Ottawa River valley (at 45.48450°N, 76.45634°W, 9.6 km northwest of the bridge in Arnprior, Renfrew County). Two were seen flying through the woods and in small openings during this period.

A colony in natural alvar woodland habitat likely feeding on the native Neglected Milk-Vetch (*Astragalus neglectus* (Torr. & A. Gray) E. Sheld.), the only legume present in alvar woodland, is of interest since it raises

the possibility that the species may have been long established in southern Ontario but very rare and local in its restricted semi-open woodland habitats. It may also represent a more or less distinct race. This possibility was further explored in 2012 through field observations and comparisons.

Observations of ovipositing females

Two females were observed laying eggs on the leaves and flower buds of Neglected Milk-Vetch on 7 June 2012. One laid two eggs, both on young inflorescences of different plants; the other laid a single egg on foliage. The Neglected Milk-Vetch plants occurred in two small more or less circular woodland openings about 15 m² in extent in a woodland of Eastern White Cedar (*Thuja occidentalis*), Balsam Fir (*Abies balsamea*), and White Spruce (*Picea glauca*) with limestone at or very near the surface. The two openings had a sparse cover of Common Juniper (*Juniperus communis*). One opening contained 25 plants of Neglected Milk-Vetch and the other opening contained 9. Other small openings in the woodland nearby also contained Neglected Milk-Vetch, but this plant was absent from the more extensive and drier areas of open alvar pavement. Neglected Milk-Vetch was the only legume species in this area and for a distance of at least 500 m.

Each of the females occupied a different woodland opening, and each remained in it for most of a full hour of observation. Both females had wings damaged in a

particular way, making individual identification possible. The females flew every 5–10 minutes and rested within 2 m of the ground on surrounding woody plants or on Neglected Milk-Vetch. Occasionally they disappeared from view into the woods for 5–10 minutes, but then returned.

Rearing larvae

The three eggs were collected and larvae were reared using simple equipment, including a wide-mouth 12 L glass jar covered with gauze tightened and held in place with a broad elastic band. Inside this, a small 200 ml glass bottle of water was placed containing a sprig of the food plant. The top of the small bottle was covered with Parafilm M (American Can Company, Greenwich, Connecticut). A small opening was made in the Parafilm cover, and the stem of the food plant was pushed to the bottom of the jar. The close fit of Parafilm around the stem prevented larvae from falling into the water and drowning and also prevented the water from being fouled with larval excrement. Two moistened paper towels in a soft ball were placed in the larger jar to maintain high humidity. The jar was placed 20 cm beneath a 22°W Daylight fluorescent lamp (Sylvania) that provided continuous light.

Characteristics of eggs, larvae, chrysalids, and adults

The three eggs were whitish with a dark area and were covered with small tubercles. Larvae hatched within 24 hours (on 8 June) and commenced to feed on flower buds and, within a few days, on the inside of

flowers, leaving most of the outer calyx intact. Feeding on leaves by the two younger larvae was very limited, but more common in the older larvae. The larvae were protected from predators during this period by resting in the hollowed-out calyx tube.

By 14 June, one larvae was 12 mm long and by 17 June the largest larva was 17–20 mm (depending on whether it was extended or resting). Mature larvae were green with a series of diagonal pale lines along the sides of each segment enclosing darker areas (resembling a very young leaf) and a darker green line longitudinally down the centre of the back and paler greenish-white or yellow lines extending longitudinally on either side (Figure 1a). The black head capsule was withdrawn into the segment behind when at rest. Larvae had a sparse covering of simple hairs but a more continuous covering of stellate hairs and two retractable tubercles on the second last segment.

Two of the mature larvae attached with silk to the upper surface of a lower leaf and formed a green chrysalis, one on 18 June and one on 20 June. Two days after beginning formation, each chrysalis had assumed a distinctive chrysalis shape. They were at first cream-coloured with numerous grey or brownish speckles. After 3–5 days, the ground colour darkened to olive green and the speckles became black spots and flecks (Figure 2). Thus the shortest duration of the larval stage under the unusual rearing conditions was 10–11 days. The first butterfly emerged on 2 July (Figure 3), 15 days after formation of the pupa. There was no emergence from the other two pupae.



FIGURE 1. Final instar larvae of the *couperi* subspecies of the Silvery Blue (*Glaucopsyche lygdamus couperi*). (a) reared from an egg laid on *Astragalus neglectus* (Neglected Milk-Vetch) on 7 June 2012 in an eastern Ontario alvar woodland near Braeside; (b) pale green larva found and reared on *Lotus corniculatus* (Garden Bird's-foot Trefoil), *Medicago albus* (White Sweet-Clover), and *Vicia cracca* (Tufted Vetch); (c) whitish larva with red dorsal stripe, frequently associated with *Vicia cracca*; (d) and purplish-pink larva found on *Medicago sativa* (Alfalfa) and *Vicia cracca*. All of the larvae in this figure were 17–20 mm long. Photo: Paul Catling (a) and Ross Layberry (b to d).

Relationship of alvar woodland Silvery Blues

In southern Ontario, the Silvery Blue is generally regarded as a recent invader using open anthropogenic habitats, such as old fields, pastures, roadsides, and woodland edges. Recent study has documented the expansion of its range southward (Layberry *et al.*, *in press*). Larvae from the Ottawa area were found and reared by RL on Tufted Vetch (*Vicia cracca*), White Sweet-Clover (*Melilotus albus*), Alfalfa (*Medicago sativa*), and Garden Bird's-foot Trefoil (*Lotus corniculatus*). Adults are also associated with Purple Crown-Vetch (*Securigera varia*) and Red Clover (*Trifolium pratense*) (PMC and RL, personal observations).

There are three possible ways in which the alvar woodland Silvery Blue may relate to the open countryside Silvery Blue: (1) they are the same, and the alvar woodland population of the Silvery Blue is recently derived from individuals of open countryside populations entering and using the alvar woodland; (2) the alvar woodland population of the Silvery Blue is long established, and this population is the source of the open countryside Silvery Blues; or (3) the alvar woodland population of the Silvery Blue is long established and is distinct and isolated from the open countryside populations.

Considering the second and third possibilities in a little more depth, the alvar woodland Silvery Blues may have been present in these habitats for a long period prior to settlement, but were always rare and local due to the restricted habitat (Catling and Brownell 1995). There are few natural habitats in southern Ontario where native legumes are common, and Neglected Milk-Vetch in alvar woodland is one of the few examples (Catling and Sinclair 2002). With regard to the third possibility, the alvar woodland Silvery Blues may have been too specialized (limited by a unique host and habitat) to expand into anthropogenic habitats, and they now exist as isolated pockets in a landscape where they are surrounded by a more aggressively expanding race of subsp. *couperi* from the north. Supporting this possibility is the fact that the nominate southern subsp. *lygdamus* is apparently unable to use non-native legumes as host plants and is restricted to a single native host plant (Dirig and Cryan 1991).

Comparisons of alvar woodland and open countryside Silvery Blues

The larvae reared from the three eggs (deposited on Neglected Milk-Vetch) were all deep green (Figure 1a), whereas the larvae from nearby open countryside sites in the Ottawa valley reared on *Lotus corniculatus*, *Melilotus albus*, and *Vicia cracca* were pale green (Figure 1b). When feeding on flowers of *Vicia cracca* or *Medicago sativa*, the larvae were either a purplish pink (Figure 1d) or white with a full or partial red dorsal stripe (Figure 1c).

It is possible that there is variation in the colour of the open countryside (*couperi*) larvae (variation among



FIGURE 2. Chrysalis of the *couperi* subspecies of the Silvery Blue (*Glaucopsyche lygdamus couperi*) reared from an egg laid on *Astragalus neglectus* (Neglected Milk-Vetch) on 7 June 2012 in an eastern Ontario alvar woodland near Braeside. Photo: Paul Catling.

populations and/or based on the colour of the material consumed). The sample here is too small to allow definite conclusions to be drawn, but it does raise the interesting possibility that the larvae from alvar woodland populations always differ in being dark green.

The chrysalids of the alvar woodland Silvery Blues (Figure 2) were similar to a few photos of those of the open country populations taken by RL.

The seven adult specimens (two males and five females) from the alvar woodland near Braeside in 2011 as well as the one female that laid two eggs and the one male reared from one of those eggs in 2012 (Figure 3) had larger spots on average than many adult specimens from northern and southern Ontario, but as a group the adult specimens from Braeside could not be definitively distinguished from subsp. *couperi* or subsp. *lygdamus*. However, they seem closer to the former. There is generally too much white around the black spots on the hindwing, the spots are too small, and the ground colour of the wings beneath is not sufficiently brownish to qualify clearly as subsp. *lygdamus*. The subsp. *lygdamus* also has a more squared-off wing shape with a darker grey ground colour, and the forewing macules are relatively closer to the margin than in subsp. *couperi*. We place the alvar woodland specimens with subsp. *couperi*.

An alvar woodland race?

The alvar woodland Silvery Blue females appear to be very localized to a particular and very small site and may even exhibit territorial behaviour. One perched female rose to meet another small butterfly (likely another female), which departed within seconds. The *Astragalus neglectus* food plants are sparse and have



FIGURE 3. Adult of the *couperi* subspecies of the Silvery Blue (*Glaucopsyche lygdamus couperi*) reared from an egg laid on *Astragalus neglectus* (Neglected Milk-Vetch) on 7 June 2012 in an eastern Ontario alvar woodland near Braeside. Photo: Jocelyn Gill.

relatively few inflorescences with relatively few flowers, and thus food resources are sparse, unlike the situation in open countryside habitats, where food plants are often frequent and large and have many inflorescences.

The isolated and very distinctive habitat and different food plant may have led to specific adaptation over thousands of years. Although two kinds cannot be definitely demonstrated, there is a possibility that the alvar woodland Silvery Blue is a distinct race that dates from early postglacial times, in contrast to the Silvery Blues elsewhere in Ontario (these Silvery Blues have originated recently from the north). Much additional work will be required to determine if this is the case, possibly including microsatellite DNA (not simple DNA barcode fingerprinting, which may not provide sufficient resolution), oviposition experiments with different hosts, study of variation in larval colour, and field studies of behaviour.

The occurrence of locally adapted races of *G. lygdamus* as well as widespread variable races has led to some degree of uncertainty in the classification of this group, but it is also of substantial evolutionary significance. Some races deserve recognition as subspecies and others do not. At least 17 variously recognized subspecies have been described (list in Miller and Brown 1981 or Pelham 2008), and several forms and aberrations have also been described. *Glaucopsyche lygdamus* also includes famous subspecies such as the Xerces Blue (subsp. *xerces* Boisduval 1852), formerly of the San Francisco region of California and for which the Xerces Society is named, and the rediscovered (Mattoni 1992) Palos Verdes Blue (subsp. *palosverdesensis* E. Perkins and J. Emmel 1977) from Los Angeles.

Regardless of the results of future taxonomic work, the possibility of a more or less distinctive race of *Glaucopsyche lygdamus couperi* being long established in southern Ontario and present in pre-settlement times is of interest in a many ways. In particular, we are unaware of the origins of a number of butterflies of open countryside that use introduced host plants. In some situations, we have seen huge increases in numbers when a butterfly switches to an introduced host (e.g., Catling *et al.* 1998). These kinds of observations relate to an understanding of the evolution and management of phytophagous insects.

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Behaviour of American Crows (*Corvus brachyrhynchos*) when Encountering an Oncoming Vehicle

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A carrion feeder attempting to forage on a road benefits greatly from an appropriate response to vehicular traffic. In this observational study, we tested the ability of American Crows (*Corvus brachyrhynchos*) to judge the behaviour of fast-moving vehicles and avoid collision on a narrow road. Unsurprisingly, American Crows feeding in the same lane as the approaching vehicle always flew off, but interestingly, a significant proportion of American Crows in the opposite lane chose to remain on the road. In addition, 21% of the American Crows in the same lane as the approaching vehicle walked over to the opposite lane to avoid injury, but none of the American Crows in the opposite lane walked over to the lane in which the vehicle was approaching. These are among the first quantitative data indicating that a non-human animal can detect the directionality of oncoming vehicles on a road and, like humans, actively move out of the way or switch lanes to avoid death based on an understanding of the behaviour of vehicular traffic.

Key Words: boldness; behavioural response; *Corvus brachyrhynchos*; American Crow; cognition; Everglades National Park; learning; road ecology; Florida

Introduction

Cognitive abilities in animals are suggested to have evolved in response to social and ecological problems that cannot be solved through simple trial and error or instinct (Kamil 1988). Such challenges include the complexities of interacting with other individuals in a group (Emery *et al.* 2007), finding food (Stephens and Krebs 1986), and avoiding predators (Bateson and Kacelnik 1998). Despite the evidence of intelligence among different taxa, relatively little is known about the selective forces driving the evolution of intelligence (Seed *et al.* 2009). Studying how organisms cope with challenges associated with foraging in new landscapes can provide an opportunity to elucidate the nature of these selective forces.

Both urban and suburban habitats host an array of wildlife populations, and use of these habitats by wildlife will only expand as urbanization increases (Ditchkoff *et al.* 2006). Roads in particular are an important component of urbanization and create movement challenges for many animals. The presence of vehicles specifically poses a threat to animals on roadways (Trombulak and Frissell 2000). However, the presence of animals killed on the roads can make roads an attractive foraging site for carrion feeders. To exploit this resource, most synanthropes (wild animals and plants that live near, and benefit from, an association with humans) avoid periods of high vehicle activity (e.g., by foraging at night) (Ditchkoff *et al.* 2006).

Feeding innovations can strongly contribute to the success of species living in a novel environment (Garamszegi *et al.* 2007). The most successful species in urban and suburban environments are those that take the greatest risks and are the most innovative feeders (Moller 2009). These traits in American Crows (*Corvus brachyrhynchos*), one of the most intelligent birds (Emery and Clayton 2004), might allow them to successfully scavenge on roads, and these traits have likely contributed to the success of American Crows in urban environments. Although several studies have focused on the adaptations of American Crows to urbanization (see Marzluff *et al.* 2001), very few studies (e.g., Cristol *et al.* 1997; Cristol and Switzer 1999; Moller *et al.* 2011) have examined their behaviour on roads.

American Crows feed on road kill (Marzluff *et al.* 2001), but are they able to judge vehicular speed and patterns of traffic flow? Such abilities might allow them both to feed on road kills by successfully trading off between food and safety and to reduce the number of situations in which they need to abandon a food source that could be stolen by a competitor or destroyed by a vehicle.

Birds and insects have a fairly sophisticated collision detection system that uses optical flow fields. This system allows them to avoid obstacles in flight (Lee and Kalmus 1980). However, to our knowledge, there are no quantitative data that show whether American Crows (or any other animal) can exploit vehicular traf-

fic lanes in order to forage and avoid injury or death from fast oncoming traffic. Consequently, we asked the following question: how good are American Crows at avoiding vehicles on roads? We addressed this question by studying the road-use behaviour of American Crows on a narrow paved two-lane road within Everglades National Park in South Florida, USA.

Birds have larger eyes in proportion to their body size than other vertebrates. This gives birds high visual acuity (defined as the minimum angular separation between two objects) at greater distances (Fernandez-Juricic *et al.* 2004). Since a larger eye has a greater number of photoreceptors, visual acuity also increases with eye size. There is a positive relationship in birds between body mass and eye size (Brooke *et al.* 1999), so larger birds are better at identifying objects at greater distances (Fernandez-Juricic *et al.* 2004). In addition, since larger birds can resolve objects earlier than small birds (Brooke *et al.* 1999), the large eyes of American Crows allow them to identify vehicles at great distances and can help American Crows to actively use roads.

This ability could also enable them to perceive whether an automobile is directly in their path and whether it poses a threat. Therefore, we predicted that scavenging American Crows in the same lane as an approaching vehicle should always fly away when they see the vehicle approaching (a natural anti-predatory locomotory response to a looming stimulus) (e.g., Gray *et al.* 2001). We predicted that they should remain on the road when a vehicle in the opposite lane approaches and passes by.

Study Area and Methods

We recorded three behavioural responses of American Crows to approaching vehicles—fly away, stay, or walk away—while they were feeding on road kill (e.g., small amphibians, reptiles, and insects), or walking and looking for food, between the Flamingo (25°08'28.96"N, 80°55'25.73"W) and Homestead gate (25°23'42.97"N, 80°34'59.36"W) within Everglades National Park on Florida State Road 9336. While travelling in a Ford F250 truck (2.5 m wide) at 80–90 km per hour (within posted speed limits), we counted the number of American Crows standing on the road and quantified their behavioural responses to our approaching vehicle.

Two observers drove a total of nine transects (seven in August 2010 and two in October 2010) along the 60 km stretch (45–50 min drive) of two-lane paved road (6.8 m wide). However, to ensure statistical independence, we used data from only a single transect between Homestead Gate and Flamingo (conducted on 21 August 2010 at around 9 AM, two hours after sunrise) for analysis. Given the speed at which our vehicle was travelling, we were confident that the same individual American Crow was unlikely to be observed at more than one location along a single transect. We chose this

single transect because it had the most observations of American Crows.

Whenever an American Crow was encountered during our drive, we made two observations: 1) the lane in which the American Crow was standing (the same lane as our vehicle or the opposite lane) and 2) the American Crow's response to our approaching vehicle (stay, fly away, or walk away). The "stay" behaviour was quantified as an instance when an American Crow continued to stand in the opposite lane while our vehicle passed by. The "fly away" behaviour was an instance in which an American Crow standing in either the same lane as the approaching vehicle or the opposite lane flew off as we approached. The "walk away" behaviour was an instance in which an American Crow walked away from the approaching vehicle, either to the opposite lane or to the curb.

Because of the risk our vehicle posed, the flight initiation distance for the American Crows was approximately 25–75 m from our approaching truck. No birds were killed by our vehicle in this study. Although State Road 9336 is used by other vehicles, we recorded the flight response only for American Crows that we approached. Generally, traffic was infrequent on this road (on average, vehicles were sighted every 5–10 minutes). While driving, we maintained a minimum distance of approximately 500 m between our vehicle and the vehicle in front of us by either overtaking slower vehicles or allowing faster vehicles to pass us.

Two species of crows are found in Everglades National Park, the more common American Crow and the rare Fish Crow (*Corvus ossifragus*). Only American Crows were recorded in this study. To determine the species of crow, we made two additional drives (not part of the analysis) along the same stretch of the road and photographed the crows on the road. The photographs were then sent to Dr. Kevin J. McGowan (Cornell Laboratory of Ornithology, Ithaca, New York), who identified them as American Crows.

A 3×2 contingency table was used to analyze whether American Crows used different behaviours (response variable) to avoid injury/death in the two lanes (explanatory variable). Since our expected numbers were small, Fisher's exact test was used to determine whether the two variables were independent of one another. Fisher's exact test is considered to be more accurate than the χ^2 test or *G*-test for any test of independence with small numbers (Zar 1999).

Results

Thirty eight American Crows (nineteen crows in the driving lane and nineteen in opposite lane) were recorded during the drive. Fisher's exact test indicated there were significant differences in the response behaviour of American Crows that were in the same lane as the approaching vehicle and American Crows that were in the opposite lane ($P < 0.0001$). No birds that were in the

same lane as the approaching vehicle chose to stay. Conditional proportions that represent the conditional distribution of the response variable (behaviour), given the explanatory variable (lanes), show that 78.95% of the American Crows in the same lane as the approaching vehicle flew away and the remaining 21.05% walked over to the opposite lane to avoid our oncoming vehicle (Figure 1). In the opposite lane, 63.16% of the American Crows remained on the road while our vehicle passed by and 36.84% flew away when our vehicle approached (Figure 1).

Discussion

As predicted, American Crows in the same lane as the approaching vehicle always moved away, either by flying away or by walking over to the opposite lane or to the curb, suggesting that American Crows are very good at determining when the trajectory of the approaching vehicle poses a threat (Figure 1). Furthermore, when American Crows are approached by a fast-moving vehicle in the opposite lane on a narrow road, a high percentage of American Crows will remain on the road (Figure 1). These lane-specific behaviours suggest that American Crows have learned that vehicles tend to drive in a straight line (do not change lanes) and in the same direction.

Why did not all American Crows decide to remain in the opposite lane or walk from the lane in which the vehicle was approaching to the opposite lane? The decision to fly often depends on the costs and benefits of escaping from predators, and this decision is context-dependent (Ydenberg and Dill 1986). Additionally, several other factors, such as an American Crow's age (experience), sex, personality (e.g., Moller 2009), or number of competitors might affect the decision to stay, move, or fly. In addition, the size of the carrion or the individual's energetic state can also play a role in an American Crow's behaviour. Controlled studies manipulating the above factors would be needed to determine the exact reasons behind the decisions of the American Crows that remained on the road.

Why did American Crows in the same lane as the approaching vehicle choose to walk to the opposite lane and remain on the road rather than walk over to the adjacent curb? One likely explanation is that the American Crows chose to walk away because they preferred having a clear sightline from which to detect a threat from the approaching vehicle. Multiple studies suggest that prey organisms prefer having a clear sightline that allows them to better detect an approaching predator and consequently manage their risk of predation (Vijayan *et al.* 2007; Embar *et al.* 2011). Since the landscape beyond the curbs on both sides of the road was grass (approximately 20 cm high), the sightline of an American Crow moving onto the curb would have been blocked, thus increasing its perceived risk of predation. Conversely, an American Crow that waited on the road in the opposite lane would continue to have a

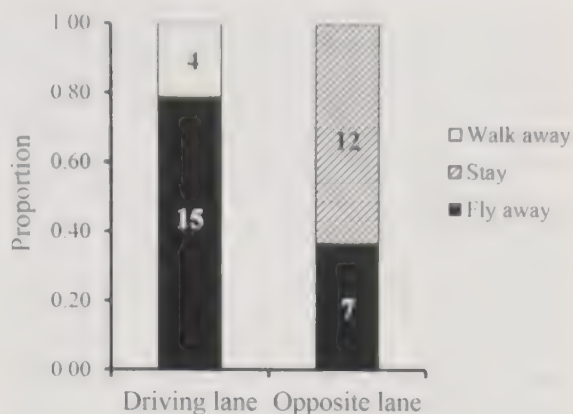


FIGURE 1. Proportional differences in behavioural responses of American Crows (*Corvus brachyrhynchos*) in the same lane as an oncoming vehicle and in the opposite lane. Numbers within bars indicate the total number of individuals observed exhibiting a particular behaviour. Note that no individuals that were in the same lane as the approaching vehicle stayed, and no individuals walked away from the opposite lane.

clear view of the approaching vehicle and would therefore feel safer. Varying grass height past the curb (this area is regularly mowed and maintained by the park authorities) can provide excellent experimental opportunities to test this concept further. According to our hypothesis, if the grass is completely mowed, American Crows should increase their preference for the grass area next to the curb, since it will be providing them with a clear sightline.

Are these behaviours unique to American Crows? No study has assessed the visual fields of perception in American Crows. To our knowledge, there are also no experimental studies that have assessed their escape response to looming objects (natural or artificial). However, it is likely that American Crows may not respond to all looming objects in the same way. American Crows have few natural predators. However, if a raptor or a Florida Panther (*Puma concolor coryi*) approached along the lane that the American Crow was in, it might not choose to wait in the opposite lane. Although we did not quantify other birds foraging on the road, we did note that all other bird species observed (e.g., sparrows; flycatchers, Turkey vulture, *Cathartes aura*) flew away when our vehicle approached, regardless of the lane they were in.

What is clear from this study is that American Crows likely are better at assessing the trajectory of a fast-moving vehicle than other birds. The ability of prey to assess and realize that a predator's approach trajectory will intercept its own trajectory helps to significantly reduce the risk of predation (Stankowich and Blumstein 2005).

Other studies have looked at flight initiation distances in urban settings (e.g., Moller 2009; Carrete and

Tella 2011), but to our knowledge this study is the first to focus on selective lane use by a bird on a road. Bold behaviour (which is commonly inferred from flight initiation distance when approached by humans) is a key characteristic of birds that colonize urban environments (Moller 2009). Even though this study was conducted in a rural setting, these American Crows might have gained experience with passing vehicles through associative learning, thus allowing them to be adept at judging a safe distance. Earlier studies on nut-cracking behaviour of Western American Crows (*Corvus brachyrhynchos hesperis*) (Cristol *et al.* 1997) and American Crows on roads (Cristol and Switzer 1999) have documented that crows fly off when a vehicle approaches. However, to our knowledge, the present study is among the first to provide quantitative data showing that American Crows (or any other bird) can judge the directionality of an approaching vehicle and react accordingly, an ability often associated with humans.

Roads form an ideal system to study learning behaviour and rapid evolution in birds, particularly their flexibility in adapting to varying environments. Our observations form a baseline that can be used to address an array of future questions. Is it a simple rule of thumb for American Crows or are they using their cognitive skills to respond (e.g., using cues such as the painted dividers to distinguish lanes)? Do American Crows take fewer chances where traffic is less predictable? How will increased traffic affect the behaviour of crows in Everglades National Park? Testing these questions will further help us understand the basis of decision making in American Crows. In particular, controlled experiments involving shifts in vehicle patterns, food manipulations, and road conditions (e.g., in sections where the road turns and multiple lane roads) are needed to comprehend the underlying mechanisms for such behaviours. Understanding how fledgling American Crows learn to use roads and lanes would be very important in strengthening this field of research. This study can be instrumental for future studies in urban ecology as well as the ethology of this group of birds.

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First Records of a Plesiosaurian (Reptilia: Sauropterygia) and an Ichthyosaur (Reptilia: Ichthyosauria) from Yukon, Canada

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An isolated centrum collected *ex situ* from marine shales of the Lower Cretaceous (Albian) Arctic Red Formation along the Road River represents the first documented occurrence of a plesiosaurian from Yukon. This centrum represents the northernmost occurrence of plesiosaurs in the Western Interior Sea of North America prior to the establishment of the first continuous seaway (Western Interior Seaway) connecting the Boreal and Tethyan seas. Additionally, this centrum is potentially the second-oldest elasmosaurid specimen known from North America. A second centrum, collected along the Beaver River, is likely derived from the Lower Cretaceous (Lower Albian) Garbutt Formation exposed farther upstream. It represents the first report of an ichthyosaur from Yukon. Additionally, six associated ribs collected from the Arctic Red Formation along the Peel River may also belong to a marine reptile; however, poor preservation of these ribs prevents a definitive taxonomic assignment.

Key Words: plesiosaurian; elasmosaurid; ichthyosaur; marine reptile; Early Cretaceous; Albian; Western Interior Sea; Arctic Red Formation; Garbutt Formation; Yukon

Introduction

The Western Interior Seaway of North America began to form during the Early Cretaceous (Aptian to Albian), when the northern Boreal and southern Tethyan seas inundated the foreland basin east of the North American Cordillera (Kauffman 1984). Plesiosaurs are known from sediments deposited in the southward-transgressing arm of the Boreal Sea prior to its first established connection with the Tethyan Sea in the Late Albian (Kauffman 1984; Druckenmiller and Russell 2008, 2009). The northernmost documented occurrences of plesiosaurs in this proto-seaway are from northern Alberta, in the Lower Albian Wabiskaw Member of the Clearwater Formation. These include elasmosaurids, polycotylids, and leptocleidids (Druckenmiller and Russell 2006, 2008, 2009). Plesiosaurs from younger, Campanian strata have also been found farther north along the Anderson River in the Northwest Territories (Russell 1967). Here, we present the first documented evidence of plesiosaurs and ichthyosaurs in Yukon (Figure 1). The plesiosaurian and ichthyosaur fossils reported here are of Early Cretaceous (early Middle Albian) and probable Early Cretaceous (Early Albian) age, respectively.

Regional Geology

The Albian (Lower Cretaceous) Arctic Red Formation of northeastern Yukon and the western Northwest Territories is a marine sequence composed predominantly of shale (Mountjoy and Chamney 1969; Thomson *et al.* 2011). The deposition of this formation represents an early incursion of the Boreal Sea into the Western Interior Basin prior to the formation of the Western Interior Seaway. This formation records deposition close to the Boreal entrance of the Western Interior Sea (Figure 2).

The Lower Albian Garbutt Formation of the Fort St. John Group, deposited during the same early incursion of the Boreal Sea, is widely distributed in the Cordilleran foothills of northern British Columbia and southern Yukon (Stott 1982; Jowett and Schröder-Adams 2005). Shales of the formation were deposited in outer shelf marine environments below storm wave base (Leckie and Potocki 1998).

Results

Systematic Palaeontology

Plesiosauria (de Blainville 1835)

Elasmosauridae indet. (Cope 1869)



FIGURE 1. Regional map showing fossil localities (ArcGIS Desktop, Release 10, Environmental Systems Research Institute (ESRI), Redlands, Calif., modified): A, Yukon Government specimen 426.1; B, Canadian Museum of Nature specimen 40559; C, Yukon Government specimen 55.1.

MATERIAL
Yukon Government Fossil Collection 426.1: an isolated centrum.

LOCALITY AND HORIZON
Yukon Government specimen 426.1 was collected in 2010 as a loose, *ex situ* element by JAC from marine shales of the Arctic Red Formation exposed along the Road River (66°42'30.196"N, 135°17'52.559"W) (Figures 1 and 3). Small dark grey accumulations of silty mudstone characteristic of the locality adhered to the outer surface of the centrum (Figure 3). Additionally, an ammonite assemblage encased in a separate loose block of silty mudstone was collected near the centrum and at the same stratigraphic horizon. Both the centrum and assemblage were found near in-place bedrock. The ammonite assemblage is composed of *Beudanticeras glabrum* (Whiteaves 1889) and cf. *Archoplites* cf. *aburens* (Spath 1933; Jeletzky 1964). These taxa are characteristic of the northern Cordilleran *Beudanticeras affine* ammonite zone of Jeletzky (1964, 1970), of early Middle Albian age (Ogg *et al.* 2012).

DESCRIPTION
Yukon Government specimen 426.1 (Figure 3) is an isolated oval centrum with amphiplatyan articular surfaces. It displays moderate erosion of its surficial bone texture. Two low-relief, parallel longitudinal ridges on the dorsal surface define the lateral margins of the neural canal. The centrum lacks rib facets, a lateral longitudinal ridge, and foramina subcentralia on the ventral surface, although each of these features, if present, may have been modified by erosion. The centrum is

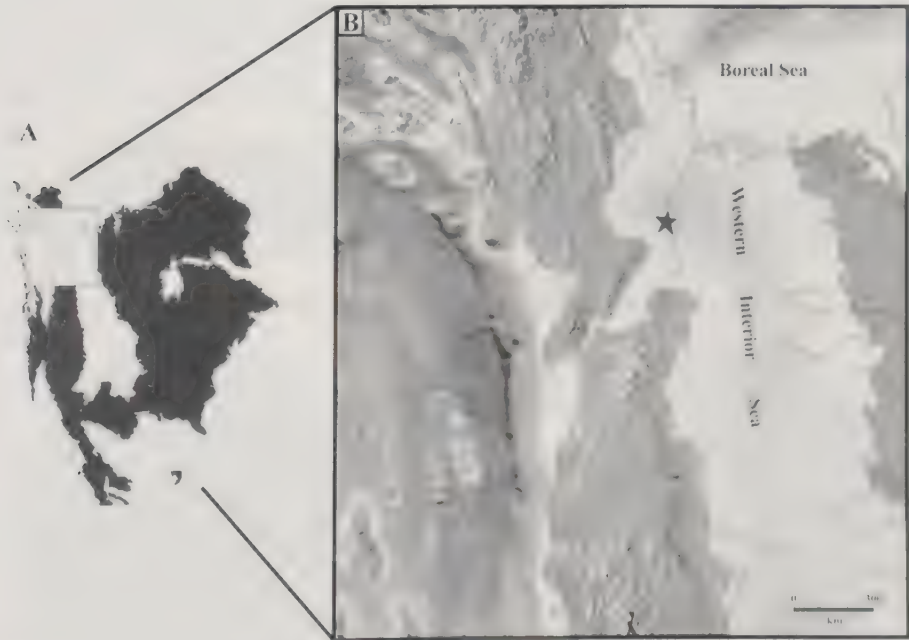


FIGURE 2. Palaeogeographic map, late Early Cretaceous (Middle to Late Albian) (Blakey 2012, modified): North America (A) and inset showing Boreal entrance of the Western Interior Sea (B). Star indicates site localities of Yukon Government specimen 426.1 and Canadian Museum of Nature specimen 40559.

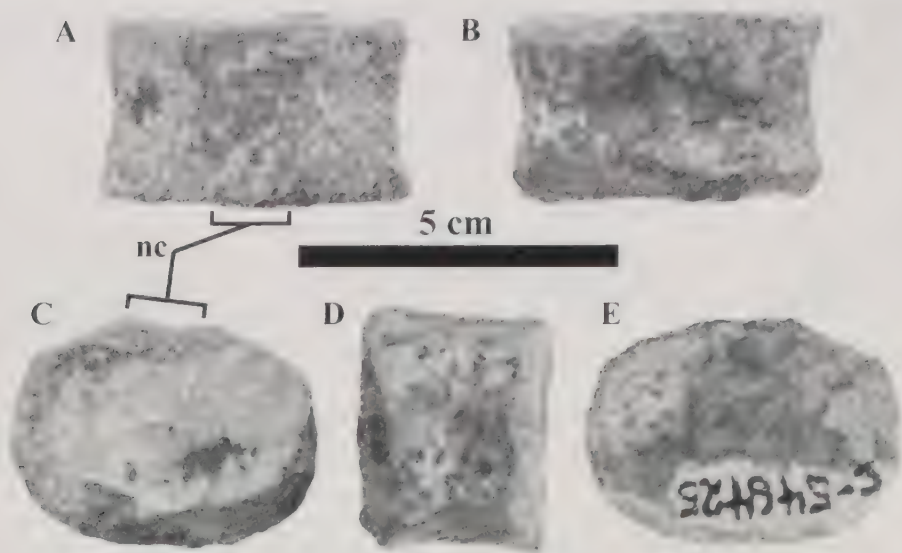


FIGURE 3. Plesiosaurian vertebra (Yukon Government specimen 426.1): dorsal view (A), ventral view (B), anterior (?) view (C), lateral view (D), and posterior (?) view (E). nc = neural canal.

approximately 4.3 cm wide, 3.3 cm high, and 2.8 cm long.

Yukon Government specimen 426.1 is interpreted to be a dorsal centrum based on its lack of rib or chevron facets, which are typical of cervical and/or caudal centra. Its ratio aspect (broader than tall) is typical of elasmosaurids, but this ratio aspect is unknown in any short-necked plesiosaurian from this time (leptocleidids, pliosaurids, and polycotylids); therefore, it is assigned to *Elasmosauridae* indet., pending the discovery of more diagnostic material. Its small size and lack of a fused neurocentral suture suggest that it is likely from a juvenile individual. However, it is also possible that the neural arch was originally present but was removed by erosion.

Ichthyosauria indet. (de Blainville 1835)

MATERIAL

Yukon Government Fossil Collection 55.1: an isolated centrum.

LOCALITY AND HORIZON

Yukon Government specimen 55.1 was surface-collected by D. MacDonald in 1998 adjacent to the Beaver River in southeastern Yukon (60°08'58.1"N, 124°58'47.4"W) (Figures 1 and 4), near an outcrop mapped as the Lower Triassic Toad Formation (Fallas and Evenchick 2006). This site corresponds to the locality of Section MWB-01-028 in MacNaughton (2002).

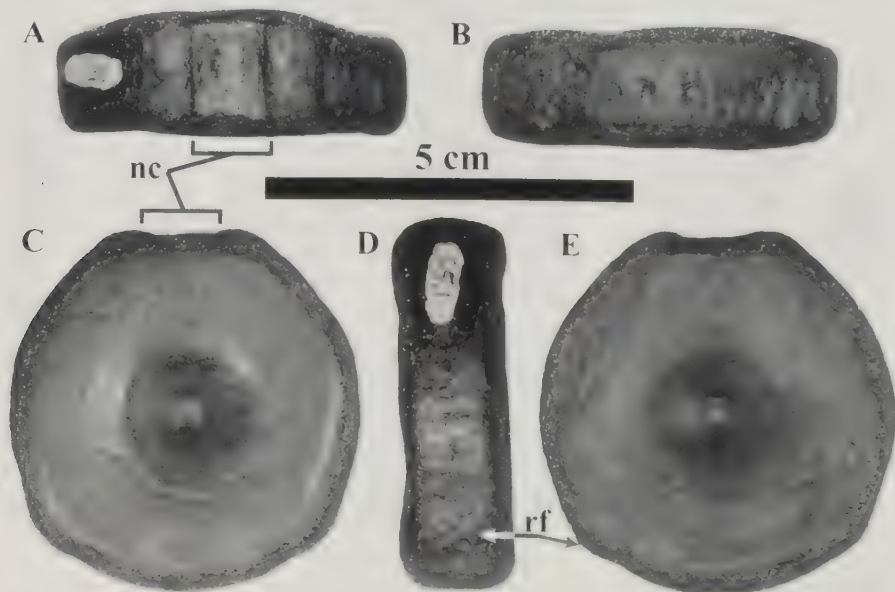


FIGURE 4. Ichthyosaur vertebra (Yukon Government specimen 55.1): dorsal view (A), ventral view (B), anterior (?) view (C), lateral view (D), and posterior (?) view (E). nc = neural canal; rf = rib facet.

DESCRIPTION

The amphicoelous centrum is moderately weathered and polished (Figure 4). The dorsal one-third of the centrum is mediolaterally narrower than the ventral one-third in articular view. Two parallel ridges define the neural canal dorsally. A single rib facet located on the ventrolateral margin of the centrum is consistent with its referral to the posterior dorsal or caudal vertebral series. It is approximately 4.6 cm wide, 4.7 cm high, and 1.5 cm long.

Yukon Government specimen 55.1 is identified as ichthyosaurian, based on its overall morphology (i.e., amphicoelous with a short anteroposterior length), which closely corresponds to described Cretaceous ichthyosaurian centra of northern Canada (e.g., *Maia-spondylus*) (Maxwell and Caldwell 2006). The centrum is larger and anteroposteriorly shorter than the much smaller ichthyopterygians known from the Lower Triassic of northern Canada, such as *Utatsusaurus* (Shikama *et al.* 1978; Nicholls and Brinkman 1993) and *Gripi-pia* (Brinkman *et al.* 1992). However, because the eroded centrum lacks other diagnostic characters, a more precise identification is not possible.

Theory on provenance of Yukon Government specimen 55.1

The derived morphology of Yukon Government specimen 55.1 is typical of Cretaceous ichthyosaurians. This suggests that it is unlikely to have come from the Lower Triassic Toad Formation. In the Beaver River region, the only non-Lower Triassic Mesozoic rocks that crop out up-valley of the ichthyosaur centrum collection site are Lower Cretaceous (Aptian to Albian) strata of the Fort St. John Group (Taylor and Stott 1999; Fallas *et al.* 2004; Fallas and Evenchick 2006; Khudoley and Fallas 2006). In ascending stratigraphic order, these units are the Chinkeh, Garbutt, and Scatter (Bulwell, Wildhorn, and Tussock members) formations (Leckie and Potocki 1998).

The Garbutt Formation has the most extensive outcrop exposure of the above units of the Fort St. John Group. This formation is the only unit that crops out along a river of significant flow—the Beaver River and, to a lesser extent, the Whitefish River. These rivers converge upstream of the collection site. The Garbutt Formation is also the closest unit to the collection site, cropping out only 4 km upstream of the site along the Beaver River. The lithology of this formation (shale) is indicative of a marine environment. For the above reasons, we consider the Garbutt Formation to be the most likely source of the morphologically derived ichthyosaur centrum. We also infer that this specimen was transported from these Lower Cretaceous (Lower Albian) rocks to its point of discovery either by river action or by glacial transport.

Other Potential Marine Reptile Material

CANADIAN MUSEUM OF NATURE specimen 40559: at least six partial ribs.

LOCALITY AND HORIZON

Canadian Museum of Nature specimen 40559 was collected by Eric Mountjoy in 1962, from a Lower Cretaceous interbedded marine shale and siltstone unit along the Peel River in northern Yukon (Mountjoy 1962*) (Geological Survey of Canada Locality 52716), 66°38'0"N, 134°28'0"W (Figures 1 and 5). The locality is approximately 50 km southeast of the location of the site where Yukon Government specimen 426.1 was collected on the Road River and has been mapped as the Arctic Red Formation (Norris 1981).

DESCRIPTION

Canadian Museum of Nature specimen 40559 represents six partial, highly weathered, broken rib shafts (Figure 5). The ribs are closely associated and sub-parallel with each other, suggesting that they may have been articulated at their time of burial. Each rib shaft is slightly curved along its long axis. The longest preserved shaft is approximately 14.7 cm in length and 0.6 cm in width. As the specimen was collected from marine shales deposited approximately 100 km from the palaeo-coastline (Blakey 2012) (Figure 2), it is likely derived from a marine animal. Based on their size and overall morphology, it is plausible to assume that these ribs belong to a marine reptile; however, its poor preservation prevents a definitive taxonomic assignment.

Palaeobiogeographic Implications of Fossil Material

The age of the ammonites associated with the plesiosaurian vertebra (Yukon Government specimen 426.1) corresponds to the period spanning the regression of the Huleross (Harmon) Sea and the initial transgression of the Joli Fou Sea, which in the early Late Albian culminated in the establishment of the first continuous marine corridor between the Boreal and Tethyan seas (Caldwell *et al.* 1978, 1993; Kauffman *et al.* 1993; Obradovich 1993; Schröder-Adams and Pedersen 2003) (Figure 2).

This vertebra represents the northernmost occurrence of plesiosaurians in the Western Interior Sea of North America prior to the establishment of the first continuous seaway (Druckenmiller and Russell 2006, 2008, 2009). Ammonite evidence also suggests that Yukon Government specimen 426.1 may represent the second oldest elasmosaurid specimen from North America, after *Wapuskaneptes betsynichollsae* from the Lower Albian Clearwater Formation of northern Alberta (Druckenmiller and Russell 2006).

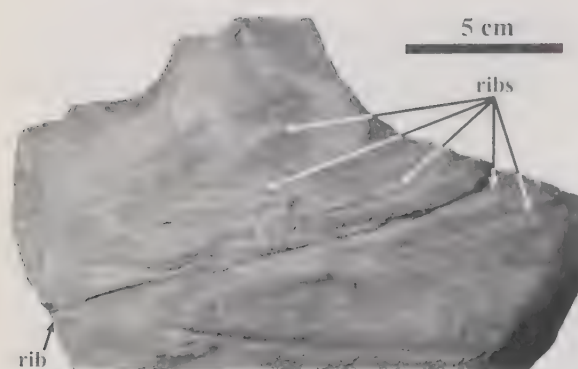


FIGURE 5. Ribs (Canadian Museum of Nature specimen 40559), likely belonging to a marine reptile (poor preservation prevents a definitive taxonomic assignment).

The plesiosaurian vertebra, as well as the ichthyosaur vertebra (Yukon Government specimen 55.1) (assuming it is Early Cretaceous in age), provides direct evidence that marine reptiles inhabited the northernmost portions of the Western Interior Sea just prior to the establishment of the Western Interior Seaway, which spanned the north-to-south length of western North America. These northern vertebrae and ribs (Canadian Museum of Nature specimen 40559) demonstrate that the Boreal Sea was likely an important entry route by which marine vertebrates moved into the seaway, and this movement ultimately resulted in a potential mixing of Boreal and Tethyan faunas.

Discussion

The Early Cretaceous (early Middle Albian) vertebra (Yukon Government specimen 426.1) and vertebra of probable Early Cretaceous (Early Albian) age (Yukon Government specimen 55.1) represent the first fossil evidence of plesiosaurians and ichthyosaurs, respectively, from the Yukon. The Albian-aged ribs (Canadian Museum of Nature specimen 40559) may also be from a marine reptile, although poor preservation precludes a definitive taxonomic assignment. Although the fossils described here cannot be identified further taxonomically, they provide new insights into the Cretaceous marine ecology of what is now Yukon. Further prospecting in the vicinity of these collection sites may reveal more taxonomically diagnostic material.

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Lichen Biodiversity and Conservation Status in the Copeland Forest Resources Management Area: A Lichen-Rich Second-Growth Forest in Southern Ontario

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Southern Ontario is the most densely populated region in Canada. As a result, urbanization, industrialization, and agriculture are extensive. Few ecosystems in the region have been unaltered, and second-growth forests now dominate the remaining natural landscape. To better understand the lichen diversity in these second-growth forests, we inventoried 24 distinct vegetation communities in the Copeland Forest Resources Management Area (1780 ha) located between Barrie and Orillia in September and October 2011, recording 154 species in 79 genera. One species, *Lecidea sarcogynoides*, was collected for the first time in Canada and is reported for the first time in North America; one additional species, *Micarea micrococca*, was collected for the first time in Ontario and is reported for the first time in Canada; three species that have previously been collected in Ontario—*Bellemerea cinereorufescens*, *Phlyctis speirea*, and *Xanthoparmelia angustiphylla*—are reported for the first time in the province; and *Candelariella lutella* was collected and is reported for the second time in Ontario and the third time in Canada. In addition, six species with a provincial status rank of S1 (critically imperilled) or S2 (imperilled) were located: *Arthonia byssacea*, *Arthonia ruana*, *Chaenothecopsis pusiola*, *Cresponea chloroconia*, *Pachyphiale fagicola*, and *Placynthiella uliginosa*. Our results show that second-growth forests can be important refugia for lichen diversity. The majority of the lichen diversity within the Copeland Forest was contained in a small number of sites (6 of 24). This suggests that management strategies should integrate lichen diversity by targeting species-rich areas. We found that sites with a high variation in: canopy closure, tree species, tree age, moisture, and the presence of snags had the highest lichen diversity. Forest managers in southern Ontario can use our results to identify species-rich areas on their properties.

Key Words: *Lecidea sarcogynoides*; *Bellemerea cinereorufescens*; *Phlyctis speirea*; *Xanthoparmelia angustiphylla*; *Candelariella lutella*; *Arthonia byssacea*; *Arthonia ruana*; *Chaenothecopsis pusiola*; *Cresponea chloroconia*; *Pachyphiale fagicola*; *Placynthiella uliginosa*; sustainable forest management; biodiversity; biogeography; Appalachian-Great Lakes; Copeland Forest Resources Management Area; Ontario

Introduction

The lichen biota of Ontario is rich and abundant; approximately 1070 species are currently known from the province (Newmaster *et al.*, in press), and the lichen biomass in some areas is over 9000 kg/ha (McMullin *et al.* 2011). The total terrestrial area of Ontario is 917 741 km², which covers a number of diverse ecoregions (Perera *et al.* 2001). Many species have specialized habitat requirements, and the diversity of the landscape accounts for the relatively large number of lichens known from the province.

Most lichen species require specific habitats, microhabitats, and substrates (Schmitt and Slack 1990; Kuusinen 1996; McMullin *et al.* 2008). This specificity includes lichen communities that change in composition along a broad bioclimatic gradient from the Arctic/alpine zone through boreal, temperate, and tropical zones. In Ontario, all but tropical conditions are present (Ahti 1964; Gowan and Brodo 1988; Brodo *et al.* 2001).

Specific ecosystems, such as bogs, cliffs, coastal areas, deserts, forests, prairies, and swamps, are the next

level of division that shapes lichen community structure (Nash 2008; Brodo *et al.* 2001). Much more specifically, many lichens require particular substrates. The substrate requirements for some species are broad, and they may grow on a range of types of bark, leaves, rocks, soil, or wood, while other lichen species require substrates as specific as particular tree species at a particular stage of development (Söderström 1988; Botting and DeLong 2009; McMullin *et al.* 2010). Defined amounts of light and moisture are also of primary importance for many lichen species (Kenkel and Bradfield 1986; Coxson and Coyle 2003; Coxson and Stevenson 2007). An understanding of the habitats that are most important for lichen diversity is therefore required to manage these organisms effectively.

Managing lichen diversity in southern Ontario presents a number of challenges. The first is a fundamental lack of baseline data: comprehensive knowledge of the lichen biota before it was altered by air pollution and development is lacking. Many lichen species are intolerant of air pollution (Henderson 2000). Although point source emissions may be controlled, much of the

air pollution in southern Ontario is wide-ranging and difficult to isolate. Extensive urban, industrial, and agricultural development is the cause of this air pollution (Bates and Sizto 1987), but this development has also resulted in the loss of much of the old-growth forest that once dominated the landscape (Henry and Quinby 2010).

Many lichen species require habitats that are characteristic of old-growth forests (Lesica *et al.* 1991; Goward 1994; McMullin *et al.* 2008), and most of those species are sensitive to changes in their environments (Esseen and Renhorn 1998; Chen *et al.* 1993; McMullin *et al.* 2010). An important part of managing lichen diversity in southern Ontario now means understanding how species colonize second-growth forests.

The purpose of this study was to better understand the lichen diversity of second-growth forests in southern Ontario by examining a representative sampling of habitats in the Copeland Forest Resources Management Area north of Barrie. Specific objectives were to (1) determine the number of lichen species in the Copeland, (2) determine the frequency of occurrence of each lichen species, (3) resolve whether alpha diversity differs among different sampling sites (vegetation

communities), and (4) identify sites with high lichen richness.

These objectives aim to produce a baseline inventory which can be used to monitor any changes in lichen diversity over time. Identifying the sites that are most important for capturing lichen diversity will assist forest managers with producing management strategies that target these areas. The results can be used in the development of sustainable management strategies, both in the study area and throughout southern Ontario in other second-growth forests.

Methods

Study area

The Copeland Forest Resources Management Area is located in southern Ontario approximately 15 km north of Barrie and 15 km west of Orillia (Figure 1). It lies between 44°32'34" and 44°35'43"N and between 79°44'31" and 79°39'19"W. Highway 400 runs along the length of the northwest side of the Copeland, and Horseshoe Valley Road runs the length of the southeast side. A continuous property covering 1780 hectares (Golas 1980), the Copeland Forest is a multi-use natural recreation area that is used mainly by



FIGURE 1. The Copeland Forest Resources Management Area with the 24 sampling sites illustrated. Sampling sites are described in Table 1.

mountain bikers, horseback riders, hikers, hunters, and crosscountry skiers. An extensive network of trails in the Copeland Forest is maintained by Horseshoe Resort for its clientele, particularly for crosscountry skiing. One of the primary rail lines connecting southern Ontario to western Canada also runs through the forest, with multiple diesel-powered trains passing through daily.

The study area lies within the Great Lakes-St. Lawrence Forest Region and is characterized by rolling hills, treed wetlands, small ponds, and deciduous mixed-wood and coniferous forests (Rowe 1972). The mean regional temperature in January is -8.4°C and in July it is 20.6°C (Environment Canada 2012). The average annual rainfall is 750.6 mm and the average snowfall is 292.6 cm (Environment Canada 2012).

Virtually all of the forested land in the study area is second-growth. The first recorded evidence of harvesting dates from 1872, but unrecorded harvesting may have occurred before that date. Harvesting continued until a mill fire on May 7, 1975 (Golas 1980). Assisted regeneration of the forest began in the 1930s and continued until the 1970s. During this time, 800,000 nursery seedlings, primarily conifers were planted (Golas 1980).

Lichen diversity

For the purposes of this study, lichen diversity is defined as lichen richness (number of species) plus abundance (frequency of occurrence of a species). To assess lichen richness, we established 24 sites that covered all of the major vegetation communities (Figure 1 and Table 1). Vegetation communities were identified using the Ontario Ministry of Natural Resources (OMNR) vegetation map for the Copeland Forest Resources Management Area. Many vegetation communities were represented by two or more spatially separate occurrences in the study area, and at least one vegetation community was included in each of the 24 sampling sites established. Once sampling sites had been selected, they were ground-truthed to determine vegetation communities accurately. Sampling sites varied in size and shape, as they followed the dominant vegetation communities.

All substrates throughout the total area of each site were examined for lichen species on September 15–18, September 30, and October 1–4, 2011. Our inventory methods follow those of Newmaster *et al.* (2005), who showed that examining large areas (referred to as floristic habitat sampling) captures cryptogam diversity more effectively than establishing smaller representative plots. Using floristic habitat sampling, our dominant mesohabitats were each of the 24 sampling sites, which included restricted mesohabitats (e.g., streams, rock outcrops, cliffs), all of which were examined for lichens. Each of the mesohabitats contained a number of microhabitats (e.g., snags, tree bases, calcareous rocks), all of which we attempted to examine. Selva (1999, 2003) also used this method for sampling lichens and refers

to it as an “intelligent meander”, as it allows more time to be spent in areas with a higher number of lichen species.

Lichen abundance was determined by the number of sampling sites in which each species occurred. A voucher specimen of each taxon was collected at each site that was inventoried.

Lichen identification

Vouchers were identified using a stereo or compound microscope and chemical spot tests with para-phenylenediamine in ethyl alcohol, nitric acid, sodium hypochlorite, 10% potassium hydroxide, and Lugol's iodine (Brodo *et al.* 2001). Chemistry was further examined using a long-wave ultraviolet light chamber. Specimens that could not be reliably identified by morphology, spot tests, or ultraviolet light were analyzed for secondary chemistry using thin-layer chromatography following Culberson and Kristinsson (1970) and Orange *et al.* (2001). Images were captured using a Panasonic Lumix DMC-ZS20 digital camera with a 20 \times optical zoom.

Voucher specimens are housed at the Biodiversity Institute of Ontario Herbarium (OAC) at the University of Guelph, Guelph, Ontario, and at the William and Lynda Steere Herbarium of the New York Botanical Garden (New York) (acronyms follow the Registry of Biological Repositories, <http://www.biorepositories.org>).

Results

One hundred and fifty-four species of lichen-forming and allied fungi in 79 genera are reported from the Copeland Forest Resources Management Area. Sixty-five species (42%) are macrolichens, and 89 species (58%) are microlichens (crustose). Of the 65 macrolichens, 29 species (19% of the 154) are fruticose in form, and 36 species (23% of the 154) are foliose. One hundred and thirty-five (88% of the 154) lichen species have green algae as their primary photobiont, 5 species (3%) have cyanobacteria as their primary photobiont, and 14 species (9%) are non-lichenized fungi traditionally treated with lichens. Fifteen species (10%) are calicioids (stubble lichens and allied fungi).

Lichen species in the Copeland Forest Resources Management Area with a provincial rank of S1 (critically imperilled) or S2 (imperilled) assigned by the Ontario Ministry of Natural Resources are (Newmaster *et al.*, in press): *Arthonia byssacea*, *Arthonia ruana*, *Chaenothecopsis pusiola*, *Cresponea chloroconia*, *Pachyphiale fagicola*, and *Placynthiella uliginosa*. Lichens from the Copeland Forest that have a low provincial rank but the rank is uncertain (either S1S3 or S2S3) are: *Anisomeridium polypori*, *Chaenothecopsis debilis*, *Porpidia cinereoatra*, and *Stenocybe major*.

Twenty species found in the study area were designated rare in southern Ontario by Wong and Brodo (1992): *Anisomeridium polypori*, *Arthonia byssacea*, *Arthonia ruana*, *Calicium trabinellum*, *Chaenothecopsis*

TABLE 1. Coordinates and habitat descriptions for the 24 lichen sampling sites in the Copeland Forest Resources Management Area north of Barrie, Ontario. See Figure 1 for locations.

Site no.	Latitude (° N)	Longitude (° W)	Habitat
1	44°35'13"	79°40'57"	Mature second-growth forest around main parking lot. Tree cover dominated by <i>Fraxinus americana</i> , <i>Picea</i> sp., and <i>Quercus rubra</i> .
2	44°35'00"	79°40'56"	Wetland along river. Moist. Protected from wind and exposed to light. Tree cover dominated by <i>Alnus incana</i> ssp. <i>rugosa</i> , <i>Picea</i> spp., <i>Pinus strobus</i> , <i>Thuja occidentalis</i> , and many snags.
3	44°34'49"	79°41'15"	Mature second-growth forest around pond. Tree cover dominated by <i>Acer rubrum</i> , <i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Thuja occidentalis</i> , and <i>Tsuga canadensis</i> .
4	44°33'57"	79°40'36"	Semi-exposed fields and forest. Tree cover dominated by <i>Pinus strobus</i> , <i>Pinus sylvestris</i> , <i>Populus tremuloides</i> , <i>Quercus rubra</i> , and <i>Rhus typhina</i> .
5	44°34'03"	79°41'02"	Small beaver pond. Tree cover dominated by <i>Pinus resinosa</i> , <i>Abies balsamea</i> , <i>Acer rubrum</i> , and <i>Quercus rubra</i> .
6	44°34'01"	79°40'27"	Wetland with pond. Tree cover dominated by <i>Acer saccharum</i> , <i>Fraxinus</i> sp., <i>Quercus rubra</i> , and <i>Thuja occidentalis</i> .
7	44°33'56"	79°49'20"	Mature second-growth forest. Exposed rock. Tree cover dominated by <i>Acer saccharum</i> and <i>Fagus grandifolia</i> .
8	44°35'21"	79°40'04"	Mature second-growth mixedwoods along the Coldwater river. Tree cover dominated by <i>Abies balsamea</i> , <i>Acer saccharum</i> , <i>Betula alleghaniensis</i> , <i>Betula papyrifera</i> , <i>Thuja occidentalis</i> , <i>Tilia americana</i> , and <i>Tsuga canadensis</i> .
9	44°34'44"	79°41'57"	Exposed grassy area along the Coldwater river. Exposed rocks. Tree cover dominated by <i>Populus balsamifera</i> , <i>Picea glauca</i> , <i>Fraxinus americana</i> , <i>Populus grandidentata</i> , and <i>Malus</i> sp.
10	44°34'06"	79°39'38"	Mature and dry second-growth forest with only deciduous trees. Tree cover dominated by <i>Acer saccharum</i> , <i>Fagus grandifolia</i> , and <i>Fraxinus americana</i> .
11	44°34'37"	79°39'33"	Young forest with a few old trees and a rock wall. Tree cover dominated by <i>Acer saccharum</i> , <i>Betula papyrifera</i> , and <i>Pinus sylvestris</i> .
12	44°34'3"	79°39'3"	Exposed rolling hills with sandy soil. Ground cover dominated by <i>Cladonia</i> subgenus <i>Cladina</i> . Tree cover dominated by <i>Acer saccharum</i> , <i>Pinus strobus</i> , <i>Pinus sylvestris</i> , <i>Quercus rubra</i> , and <i>Rhus typhina</i> .
13	44°33'2"	79°43'4"	Treed wetland and swamp. Numerous stumps and snags. Tree cover dominated by <i>Abies balsamea</i> , <i>Acer rubrum</i> , <i>Alnus incana</i> ssp. <i>rugosa</i> , <i>Picea glauca</i> , <i>Pinus strobus</i> , and <i>Thuja occidentalis</i> .
14	44°32'54"	79°43'30"	Exposed wetland. Cement culvert. Decorticated snags.
15	44°34'01"	79°42'41"	Mature second-growth mixedwood forest. Tree cover dominated by <i>Acer rubrum</i> , <i>Acer saccharum</i> , <i>Pinus strobus</i> , <i>Populus</i> spp., and <i>Tsuga canadensis</i> .
16	44°34'31"	79°42'21"	Mature and moist second-growth forest around pond and wetland. Tree cover dominated by <i>Acer saccharum</i> , <i>Acer rubrum</i> , <i>Betula alleghaniensis</i> , <i>Betula papyrifera</i> , and <i>Tsuga canadensis</i> .
17	44°35'32"	79°40'13"	Mature second-growth forest on either side of a small stream. Tree cover dominated by <i>Acer rubrum</i> , <i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Pinus strobus</i> , and <i>Tsuga canadensis</i> .
18	44°34'58"	79°39'43"	Mature second-growth forest on steep ridges. Tree cover dominated by <i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Quercus rubra</i> , and <i>Tsuga canadensis</i> .
19	44°34'45"	79°40'06"	Moist valley. Mature second-growth trees around small pond. Exposed sandy soil. Tree cover dominated by <i>Betula alleghaniensis</i> , <i>Betula papyrifera</i> , <i>Fagus grandifolia</i> , and <i>Tsuga canadensis</i> .
20	44°34'10"	79°41'29"	Wet, swampy. Mature trees. Tree cover dominated by <i>Abies balsamea</i> , <i>Acer rubrum</i> , <i>Populus balsamifera</i> , and <i>Thuja occidentalis</i> .
21	44°33'32"	79°41'22"	Grassy field with sandy soil. Surrounding tree cover dominated by <i>Acer saccharum</i> , <i>Fraxinus americana</i> , <i>Pinus resinosa</i> , <i>Pinus sylvestris</i> , and <i>Quercus rubra</i> .
22	44°33'30"	79°41'41"	Mature second-growth forest on either side of an old decommissioned road. Tree cover dominated by <i>Acer saccharum</i> , <i>Quercus rubra</i> , and <i>Tsuga canadensis</i> .
23	44°33'06"	79°41'58"	Moist, young forest. Tree cover dominated by <i>Abies balsamea</i> and <i>Thuja occidentalis</i> .
24	44°34'39"	79°40'40"	Mature second-growth forest. Tree cover dominated by <i>Acer saccharum</i> , <i>Betula papyrifera</i> , <i>Fraxinus</i> spp., <i>Tilia americana</i> , and <i>Tsuga canadensis</i> .

debilis, *Chaenothecopsis pusiola*, *Cladonia digitata*, *Cladonia parasitica*, *Cresponea chloroconia*, *Multi-clavula mucida*, *Parmeliopsis hyperopta*, *Phaeocalicium polyporaenum*, *Phaeocalicium populneum*, *Placynthiella uliginosa*, *Sphinctrina anglica*, *Stenocybe pullatula*, *Stenocybe major*, *Stereocaulon tomentosum*, *Usnea subfloridana*, and *Vulpicida pinastri*. One species found in the Copeland Forest, *Pachyphiale fagicola* (Figure 2D), was designated very rare by Wong and Brodo (1992).

We also recorded 25 species that were not listed by Wong and Brodo (1992) in southern Ontario: *Acarospora moenium*, *Arthonia caudata*, *Arthonia helvola*, *Bellemerea cinereorufescens*, *Biatora chrysantha*, *Caloplaca pyracea*, *Candelariella lutella*, *Chaenotheca xyloxena*, *Chaenothecopsis exilis*, *Cladonia ochrochlorea*, *Dictyocatenulata alba*, *Illosporopsis christiansenii*, *Lecania croatica*, *Lecidea sarcogynoides*, *Lepraria elobata*, *Melanelixia fuliginosa*, *Micarea micrococca*, *Violella fucata*, *Peltigera extenuata*, *Phlyctis speirea*, *Porpidia cinereoatra*, *Protoparmelia hypotremella*,

Ropalospora viridis, *Xanthomendoza ulophyllodes*, and *Xanthoparmelia angustiphylla*.

Based on a current, but unpublished, lichen list for Ontario, two of the species found in the Copeland Forest are new records for the province: *Lecidea sarcogynoides* and *Micarea micrococca* (Figure 2A–B). *Lecidea sarcogynoides* is also a new Canadian record, based on an unpublished national microlichen checklist that is currently being developed (Brodo, personal communication, May 2012). *Micarea micrococca* is reported for the first time in Canada. It was previously collected in Newfoundland, Newfoundland and Labrador. Three species found during our study are reported for the first time in Ontario: *Bellemerea cinereorufescens* (Figure 2C), *Phlyctis speirea*, and *Xanthoparmelia angustiphylla*. *Bellemerea cinereorufescens* is known from two previous collections in the province and *Phlyctis speirea* and *Xanthoparmelia angustiphylla* are both known from one previous collection. *Candelariella lutella* is collected and reported for the second time in Ontario and the third time in Canada.

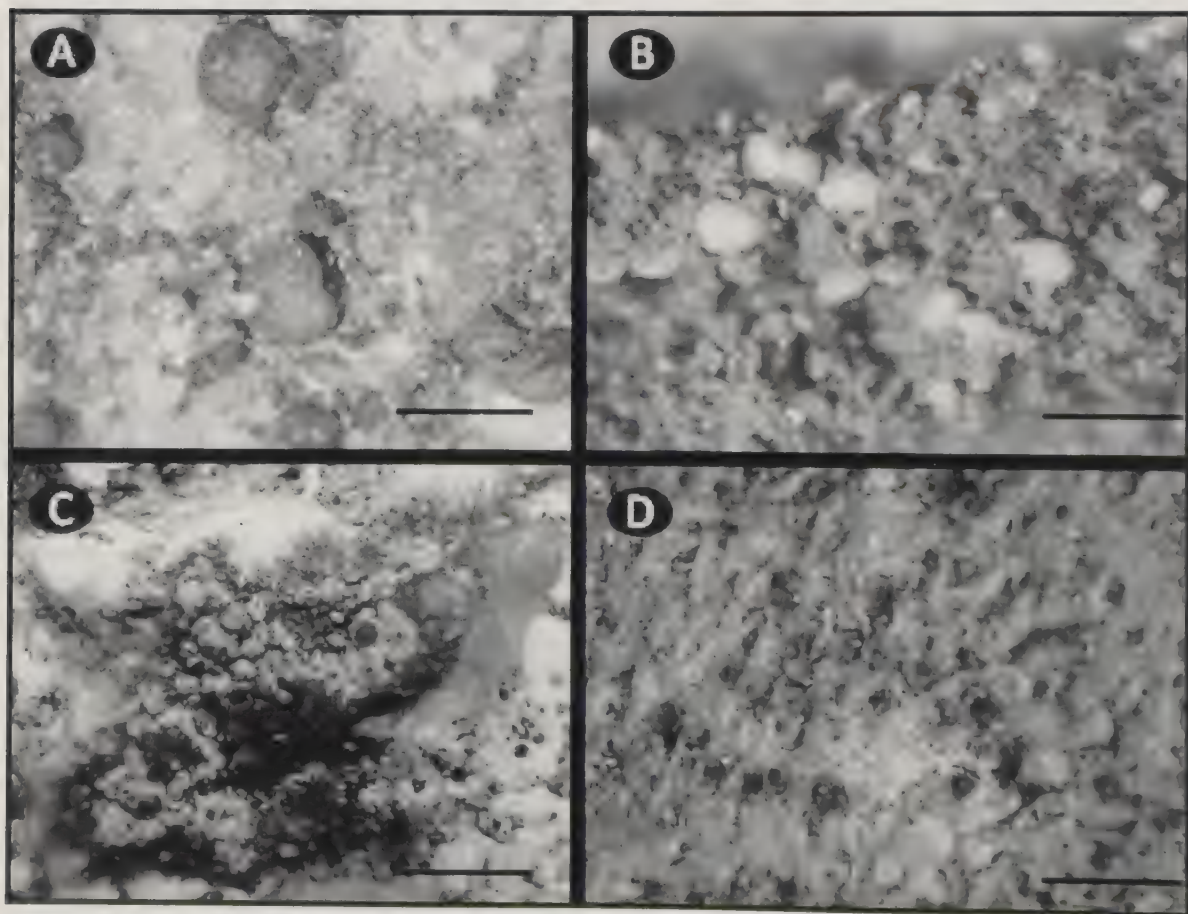


FIGURE 2. A and B are lichen species new to Ontario. A. *Lecidea sarcogynoides*, scale = 0.6 mm, McMullin 9106, New York. B. *Micarea micrococca*, scale = 0.4 mm, McMullin 9150, NY. C. *Bellemerea cinereorufescens*, scale = 2.5 mm, McMullin 8959, OAC. D. *Pachyphiale fagicola*, scale = 1.5 mm, McMullin 9136, OAC.

Of the 154 taxa found during this study, none occurred in all of the 24 study sites examined in the Copeland Forest. Nineteen species were located in 7 or more sites, while 68 species were found at only a single site.

Substrate-specific species were found colonizing the following substrata exclusively: deciduous trees (26 species), rocks (21 species), snags (19 species), soil (15 species), coniferous trees (7 species), stumps (6 species), *Acer saccharum* (5 species), cement (5 species), *Populus balsamifera* (3 species), *Quercus rubra* (3 species), *Rhus typhina* (3 species), *Thuja occidentalis* (3 species), *Abies balsamea* (2 species), *Betula alleghaniensis* (2 species), *Pinus strobus* (2 species), *Acer rubrum* (1), *Alnus incana* ssp. *rugosa* (1 species), and a polypore (1 species).

Within the 24 sites in the Copeland Forest (Table 1), the highest number of lichen species was in site numbers 2 (42 species), 12 (40 species), 16 (40 species), 8 (37 species), 9 (38 species), and 13 (33 species).

Annotated species list

The annotated checklist presented below is arranged alphabetically by genus and species. Authority abbreviations follow Brummitt and Powell (1996). Taxonomy follows Esslinger (2012). In cases where the list deviates from Esslinger (2012), it reflects the taxonomic opinions of the authors.

Non-lichenized fungi treated with lichens are preceded by a dagger (†). Species preceded by an asterisk (*) are reported (published) for the first time in Ontario. Species preceded by two asterisks (**) were collected for the first time in Ontario.

S and G ranks are conservation status ranks assigned by the Ontario Ministry of Natural Resources that are not legal determinations. S ranks are provincial designations and G ranks are global designations. Conservation status is designated by a number between 1 and 5: 1 = critically imperilled, 2 = imperilled, 3 = vulnerable, 4 = apparently secure, 5 = secure, U = "unrankable" due to a lack of information, ? = rank uncertain, NR = reported but without verification or persuasive documentation (Ontario Ministry of Natural Resources 2012).

Frequency designations for species in southern Ontario follow the S and G ranks and are non-legal determinations by Wong and Brodo (1992). Their designations are based on the number of counties (36 total) a species was collected in: very rare = 1 county, rare = 2 or 3 counties, frequent = 4 or 5 counties, common = 6 to 8 counties, very common = 9 to 36 counties.

The site number identifying the site in which each species was collected is in bold. The substrate that each specimen was growing on follows the site number.

Collection numbers of RTM follow the substrates of each specimen and are housed at OAC unless stated otherwise.

- Acarospora fuscata* (Schrad.) Arnold: **12** – granitic rock, 8690, 8960. **16** – granitic rock, 8537. S5, G5; very common (Wong and Brodo 1992).
- Acarospora moenium* (Vain.) Räsänen: **9** – cement culvert over water, 9139 (NY, OAC). SNR, GNR; not reported by Wong and Brodo (1992).
- Amandinea dakotensis* (H. Magn.) P. May & Sheard: **12** – *Rhus typhina*, 8878. S4, GNR; infrequent (Wong and Brodo 1992).
- Amandinea punctata* (Hoffm.) Coppins & Scheid.: **4** – *Quercus rubra*, 9155 (NY). **6** – snag, 9252. S5, G5; very common (Wong and Brodo 1992).
- Anisomeridium polypori* (Ellis & Everh.) M.E. Barr: **10** – deciduous tree, 9148 (NY, OAC). **17** – *Betula alleghaniensis*, 9144 (NY). **20** – *Thuja occidentalis*, 9146 (NY). S2S3, GNR; rare (Wong and Brodo 1992).
- Arthonia byssacea* (Weigel) Almq.: **8** – snag, 9113 (NY, OAC). S1S2, GNR; rare (Wong and Brodo 1992).
- Arthonia caesia* (Flot.) Körb.: **1** – *Fraxinus*, 8798. **4** – *Quercus rubra*, 8502. **9** – *Prunus*, 8501; *Malus*, 8770. S5, G4G5; common (Wong and Brodo 1992).
- Arthonia caudata* Willey: **4** – *Pinus strobus*, 8508. **12** – *Pinus strobus*, 9280. SNR, GNR; not reported by Wong and Brodo (1992).
- Arthonia helvola* (Nyl.) Nyl.: **2** – *Betula alleghaniensis*, 8509. **16** – *Betula alleghaniensis*, 8503. SNR, GNR; not reported by Wong and Brodo (1992).
- Arthonia ruana*. Massal.: **16** – *Acer saccharum*, 9123. S1, GNR; rare (Wong and Brodo 1992).
- Aspicilia cinerea* (L.) Körb.: **12** – siliceous rock, 8731. S4S5, G5; frequent (Wong and Brodo 1992).
- Bacidia schweinitzii* (Fr. ex Tuck.). Scheid.: **8** – *Acer saccharum*, 8504. **19** – *Fagus grandifolia* snag, 8732. **20** – *Thuja occidentalis*, 9224. **23** – *Thuja occidentalis*, 9151 (NY, OAC). S5, G4G5; common (Wong and Brodo 1992).
- **Bellemeria cinereorufescens* (Ach.) Clauzade & Cl. Roux: **12** – siliceous rock, 8959. SU, GNR; not reported by Wong and Brodo (1992).
- Biatora chrysantha* (Zahlbr.) Printzen: **13** – soil, 9132 (NY). SNR, GNR; not reported by Wong and Brodo (1992).
- Bilimbia sabuletorum* (Schreber) Arnold: **20** – *Thuja occidentalis*, 8979. S5, G4G5; common (Wong and Brodo 1992).
- Buellia erubescens* Arnold: **2** – *Alnus*, 8505. **9** – *Malus*, 8734. **20** – *Acer rubrum*, 8733. SNR, G3G5; frequent (Wong and Brodo 1992).
- Calicium trabinellum* (Ach.) Ach.: **13** – lignicolous, charred stump, 8627; lignicolous, stump, 8080. S4S5, G4G5; rare (Wong and Brodo 1992).
- Caloplaca cerina* (Ehrh. ex Hedw.) Th. Fr.: **8** – snag, 8843. **9** – *Populus balsamifera*, 8723, 8783. S5, G5; frequent (Wong and Brodo 1992).

- Caloplaca feracissima* H. Magn.: **14** – cement culvert over water, 9149 (NY, OAC). **16** – cement culvert over water, 9154 (NY). S5, G5?; common (Wong and Brodo 1992).
- Caloplaca holocarpa* (Hoffm. ex Ach.) A.E. Wade: **9** – cement culvert over water, 8515. S5, G5; common (Wong and Brodo 1992).
- Caloplaca pyracea* (Ach.) Th. Fr.: **9** – *Populus balsamifera*, 8510, 8722. S5, G5; included with *C. holocarpa* by Wong and Brodo (1992).
- Candelaria concolor* (Dicks.) Stein: **1** – *Fraxinus*, 8794. **3** – deciduous snag, 8826. **4** – *Quercus rubra*, 8853. **8** – *Acer saccharum*, 8507; snag, 8842; *Abies balsamea*, 8848. **9** – *Malus*, 8767, 8777. **11** – *Acer*, 8860. **17** – *Acer saccharum*, 8840. S5, G5; very common (Wong and Brodo 1992).
- Candelariella aurella* (Hoffm.) Zahlbr.: **9** – cement culvert over water, 8506. **16** – cement culvert over water, 8998. S5, G5?; common (Wong and Brodo 1992).
- Candelariella efflorescens* R.C. Harris & W.R. Buck: **1** – *Quercus rubra*, 9138 (NY). **9** – *Populus balsamifera*, 8764. **13** – *Prunus*, 8511, 8512; *Acer rubrum*, 8994; *Thuja occidentalis* snag, 8995. **16** – *Acer rubrum*, 8994. **23** – *Thuja occidentalis*, 8997. S5, G4G5; common (Wong and Brodo 1992).
- Candelariella lutella* (Vain.) Räsänen: **9** – *Populus balsamifera*, 9281. SNR, GNR; not reported by Wong and Brodo (1992).
- Candelariella vitellina* (Hoffm.) Müll. Arg.: **12** – granitic rock, 8762. S5, G5; very common (Wong and Brodo 1992).
- Cetrelia olivetorum* (Nyl.) W.L.Culb. & C.F.Culb.: **1** – *Quercus rubra*, 9258. **2** – deciduous snags, 8513, 8514. S4, G3G5; frequent (Wong and Brodo 1992).
- Chaenotheca ferruginea* (Turner ex Sm.) Mig.: **2** – lignicolous snag, 8078. **8** – *Thuja occidentalis*, 8735. **17** – lignicolous snag, 8070. S4, G4G5; infrequent (Wong and Brodo 1992).
- Chaenotheca furfuracea* (L.) Tibell: **3** – fine tree roots in moist cavern, 8086. **19** – tree roots in a moist, sheltered environment, 9020. S4, G4G5; infrequent (Wong and Brodo 1992).
- Chaenotheca xyloxena* Nádv.: **17** – decorticated snags, 8060, 8073, 8075. SNR, GNR; not reported by Wong and Brodo (1992).
- †*Chaenothecopsis debilis* (Turner & Borrer ex Sm.) Tibell: **2** – *Thuja occidentalis* snag, 8094. **8** – wooden fence post, 8087. **10** – lignicolous snag, 8091. S2S3, GNR; rare (Wong and Brodo 1992).
- †*Chaenothecopsis exilis* Tibell: **16** – decorticated snag, 8068. **17** – decorticated snag, 8071. SNR, GNR; not reported by Wong and Brodo (1992).
- †*Chaenothecopsis pusiola* (Ach.) Vain.: **17** – decorticated snags, 8059, 8074. S1S2, GNR; rare Wong and Brodo (1992).
- †*Chaenothecopsis* spp.: **2** – decorticated snags, 9287, 9288. **8** – decorticated snag, 8058. **9** – decorticated snag, 9246. **13** – decorticated snag, 8093. **17** – decorticated snag, 8076. Notes: These specimens appear to be undescribed species.
- Cladonia acuminata* (Ach.) Norrl.: **4** – sandy soil, 8700. SNR, G5?; infrequent (Wong and Brodo 1992).
- Cladonia cenotea* (Ach.) Schaer.: **13** – stump, 8518. S5, G5; frequent (Wong and Brodo 1992).
- Cladonia chlorophaea* (Flörke ex Sommerf.) Spreng.: **2** – *Thuja occidentalis* snag, 8541; stump, 9271. **4** – sandy soil, 9264. **7** – base of *Fagus grandifolia*, 9277. **8** – *Thuja occidentalis*, 9265. **10** – the base of *Acer saccharum*, 8519. **11** – soil, 9275. **12** – sandy soil, 9272. **13** – stump, 9273. **15** – soil, 9274. **16** – *Acer saccharum*, 9270; fence post, 9276. **19** – sandy soil, 9266, 9268, 9269. S5, GU; very common (Wong and Brodo 1992).
- Cladonia coniocraea* (Flörke) Spreng.: **2** – coarse woody debris, 8520; *Betula papyrifera* snag, 8523; *Tsuga canadensis* snag, 8788. **8** – *Tsuga canadensis* snag, 8524; stump; 8525. **10** – coarse woody debris, 8521. **13** – stump, 8522. S5, G5; very common (Wong and Brodo 1992).
- Cladonia cristatella* Tuck.: **2** – snag, 8888. **6** – snag, 8526. **12** – soil, 8527–8529. **13** – decorticated stump, 8940. **15** – soil, 8530. **16** – soil, 8701. **19** – soil, 8531. **21** – soil, 8992. S5, G5?; very common (Wong and Brodo 1992).
- Cladonia digitata* (L.) Hoffm.: **10** – base of an *Acer saccharum*, 8532. S4S5, G3G5; rare (Wong and Brodo 1992).
- Cladonia fimbriata* (L.) Fr.: **2** – *Thuja occidentalis* snag, 8789. **4** – sandy soil, 8534, 8702. **8** – *Tsuga canadensis* snag, 8535. **10** – *Acer saccharum*, 8533. **13** – *Acer rubrum*, 8536; *Prunus*, 8538. **16** – *Betula alleghaniensis*, 8703. **19** – sandy soil, 8539, 8704. S5, G3G5; common (Wong and Brodo 1992).
- Cladonia grayi* G. Merr. ex Sandst.: **2** – *Thuja occidentalis* snag, 8540. **13** – soil, 8626. S4S5, GU; frequent (Wong and Brodo 1992).
- Cladonia macilenta* var. *bacillaris* (Ach. Schaer.: **6** – decorticated coarse woody debris, 8628. **10** – base of an *Acer saccharum*, 8544. S5, G5T5; common (Wong and Brodo 1992).
- Cladonia mitis* Sandst.: **12** – sandy soil, 8516, 8517, 8543. **16** – soil, 8699. SNR, GNR; common Wong and Brodo (1992).
- Cladonia ochrochlora* Flörke: **2** – stump, 8545. **11** – coarse woody debris, 9267. **17** – base of a snag, 8705. **19** – coarse woody debris, 8546, 8547. **23** – soil, 8990. SNR, G3G5; not reported by Wong and Brodo (1992).

- Cladonia parasitica* (Hoffm.) Hoffm.: **10** – snag, 8548. SNR, G3G5; rare (Wong and Brodo 1992).
- Cladonia phyllophora* Hoffm.: **12** – soil, 8549, 8550, 8707; sandy soil, 8553. **19** – on soil, 8706. S5, G5; common (Wong and Brodo 1992).
- Cladonia pleurota* (Flörke) Schaer.: **12** – sandy soil, 8551, 8552. **16** – soil, 8709. S5, G3G5; frequent (Wong and Brodo 1992).
- Cladonia pyxidata* (L.) Hoffm.: **4** – sandy soil, 8858. **8** – *Thuja occidentalis*, 8554. **12** – sandy soil, 8555–8557. S5, G5; very common (Wong and Brodo 1992).
- Cladonia rangiferina* (L.) F.H. Wigg.: **4** – sandy soil, 8720. **6** – snag, 8558. **11** – soil, 8559. **12** – sandy soil, 8560–8562. **16** – soil, 8712. **19** – sandy soil, 8711. S5, G5; common (Wong and Brodo 1992).
- Cladonia rei* Schaer.: **2** – *Thuja occidentalis* snag, 9257. **4** – sandy soil, 8563, 8714, 9278. **19** – sandy soil, 8564, 8713, 9279. **21** – soil, 8982. S5, G3G5; very common (Wong and Brodo 1992).
- Cladonia turgida* Hoffm.: **12** – soil, 8565. **19** – soil, 8566, 8715. S5, G3G5; common (Wong and Brodo 1992).
- Cladonia uncialis* (L.) F.H. Wigg.: **12** – sandy soil, 8567–8569, 8708. **19** – sandy soil, 8716. S5, G4G5; frequent (Wong and Brodo 1992).
- Cladonia verticillata* (Hoffm.) Schaer.: **4** – sandy soil, 8519. **12** – sandy soil, 8570, 8571, 8857. **15** – soil, 8572. **16** – soil, 8717. **19** – sandy soil, 8573, 8718. S4S5, G5TNR; very common (Wong and Brodo 1992).
- Coenogonium pineti* (Ach.) Lücking & Lumbsch: **5** – *Betula alleghaniensis*, 8847. **13** – base of an *Acer rubrum*, 8632. **20** – *Thuja occidentalis*, 9225. S3, GNR; infrequent (Wong and Brodo 1992).
- Cresponea chloroconia* (Tuck.) Egea & Torrente: **2** – *Thuja occidentalis* snags, 8629, 8630. S1S2, GNR; rare (Wong and Brodo 1992).
- Dictyocatenulata alba* Finley & E.F. Morris: **2** – *Betula alleghaniensis*, 8574. **5** – *Betula alleghaniensis*, 8736. SNR, GNR; not reported by Wong and Brodo (1992).
- Evernia mesomorpha* Nyl.: **2** – snag, 8575; *Thuja occidentalis* snag, 8810; *Pinus strobus*, 8576. **5** – *Abies balsamea*, 8812. **8** – *Abies balsamea*, 8790. **9** – *Prunus*, 8577; *Malus* 8867. **10** – snag, 8951. **11** – *Pinus resinosa*, 8949. **12** – snag, 8802; *Rhus typhina*, 8578. **16** – *Pinus sylvestris* snag, 8939. S5, G5; common (Wong and Brodo 1992).
- Flavoparmelia caperata* (L.) Hale: **1** – *Fraxinus*, 8797. **2** – *Thuja occidentalis* snag, 8579; snag, 8830. **8** – *Thuja occidentalis*, 8866. **9** – *Prunus*, 8580; snag, 9220. **10** – snag, 8953. **13** – *Prunus*, 8581; *Picea glauca*, 8582. **16** – snag, 8862; *Pinus sylvestris* snag, 8938. **20** – *Thuja occidentalis*, 8863. S5, G5?; very common (Wong and Brodo 1992).
- Flavopunctelia flaventior* (Stirt.) Hale: **9** – snag, 9218. S5, G5; common (Wong and Brodo 1992).
- Graphis scripta* (L.) Ach.: **2** – *Betula alleghaniensis*, 8583. **3** – *Acer saccharum*, 8822. **5** – *Betula alleghaniensis*, 8846. **8** – *Acer saccharum*, 8584; deciduous snag, 8883. **11** – *Acer*, 8585; *Acer saccharum*, 8874. **13** – *Quercus rubra*, 8586. **16** – *Betula alleghaniensis*, 8587; *Acer saccharum*, 8814, 8877. **18** – *Acer saccharum*, 8588. **22** – *Acer saccharum*, 8980. **24** – *Acer saccharum*, 8986. S5, G5; very common (Wong and Brodo 1992).
- Hypocnomyce friesii* (Ach.) P. James & Gotth. Scheid.: **13** – charred decorticated stump, 8589. SNR, G3G5; infrequent (Wong and Brodo 1992).
- Hypocnomyce scalaris* (Ach. ex Lilj.) M. Choisy: **13** – charred decorticated stumps, 8590, 8591. S5, G5; very common (Wong and Brodo 1992).
- Hypogymnia physodes* (L.) Nyl.: **2** – snag, 8592; *Pinus strobus*, 8765; *Thuja occidentalis* snag, 8809; deciduous snag, 8837. **5** – *Abies balsamea*, 8813. **8** – *Abies balsamea*, 8593. **11** – *Pinus resinosa*, 8948. **13** – decorticated stump, 8943. **16** – *Pinus sylvestris* snag, 8935. **17** – snag, 8801. S5, G5; very common (Wong and Brodo 1992).
- †*Illosporopsis christiansenii* (B. L. Brady & D. Hawksw.) D. Hawks: **1** – *Physcia stellaris*, 8631; **9** – *Physcia stellaris*, 8774, 8954. SNR, GNR; not reported by Wong and Brodo (1992).
- Imshaugia aleurites* (Ach.) S.F. Mey.: **2** – branch of *Thuja occidentalis* snag, 8594. S4S5, G5, frequent (Wong and Brodo 1992).
- †*Julella fallaciosa* (Arnold) R.C. Harris: **2** – *Betula papyrifera*, 9263. **8** – *Acer saccharum*, 8962. **10** – *Acer saccharum*, 8738. **11** – *Acer saccharum*, 8963. **16** – *Acer saccharum*, 8964; *Betula papyrifera* 9262. **17** – *Acer saccharum*, 8737. **18** – *Acer saccharum*, 8966. **22** – *Acer saccharum*, 8967. **24** – *Acer saccharum*, 8965. SNR, GNR; frequent (Wong and Brodo 1992).
- Lecania croatica* (Zahlbr.) Kotlov: **2** – *Acer saccharum*, 8970. **8** – *Acer saccharum*, 8971, 8972. **9** – snag, 8968. **19** – snag, 8969. SNR, GNR; not reported by Wong and Brodo (1992).
- Lecania naegelii* (Hepp) Diederich & v.d. Boom: **1** – *Fraxinus*, 8595, 8596. **4** – *Populus balsamifera*, 8597. **9** – *Populus balsamifera*, 8598, 8739; *Fraxinus*, 9254. S2S4, GNR; infrequent (Wong and Brodo 1992).
- Lecanora albella* (Pers.) Ach. var. *rubescens* (Imshaug & Brodo) Lumbsch: **13** – *Pinus strobus*, 8961. SNR, G4G5TNR; frequent (Wong and Brodo 1992).
- Lecanora caesiorubella* Ach. subsp. *caesiorubella*: **20** – *Acer rubrum*, 8740. S4S5, G4G5TNR; frequent (Wong and Brodo 1992).
- Lecanora hybocarpa* (Tuck.) Brodo: **2** – snag, 9250. **9** – *Populus balsamifera*, 8599; *Fraxinus*, 9255.

- 13** – deciduous bark, 8600. S4S5, G5; common (Wong and Brodo 1992).
- Lecanora meridionalis* H. Magn.: **13** – stump, 9001. SNR, GNR; infrequent (Wong and Brodo 1992).
- Lecanora muralis* (Schreb.) Rabenh.: **12** – rock, 9104 (NY). S5, G5; common (Wong and Brodo 1992).
- Lecanora polytropa* (Hoffm.) Rabenh.: **9** – siliceous rock, 8820. S5, G5; frequent (Wong and Brodo 1992).
- Lecanora pulicaris* (Pers.) Ach.: **2** – *Pinus strobus*, 8729. **4** – *Pinus strobus*, 8845. **5** – *Abies balsamea*, 8811; snag, 8851. **12** – *Pinus strobus*, 8601. **13** – *Picea glauca*, 8602, 8724. S5, G5; common (Wong and Brodo 1992).
- Lecanora rugosella* Zahlbr.: **2** – *Thuja occidentalis* snags, 8603, 8871. **8** – *Thuja occidentalis*, 8604. **20** – *Thuja occidentalis*, 9223. S4S5, G5?; frequent (Wong and Brodo 1992).
- Lecanora symmicta* (Ach.) Ach.: **1** – *Fraxinus*, 8605. **2** – *Pinus strobus*, 8730. **5** – snag, 8852. **9** – *Prunus*, 8606; *Populus balsamifera*, 8784. **13** – *Picea glauca*, 8725; stump, 8941, 8975. **16** – *Pinus sylvestris* snag, 8936. **17** – snag, 8800. S5, G5; common (Wong and Brodo 1992).
- Lecanora thysanophora* R.C. Harris: **1** – *Fraxinus*, 8796. **2** – *Thuja occidentalis* snag, 8607; *Acer*, 8608. **8** – *Acer saccharum*, 8609. **11** – *Acer saccharum*, 8610. **16** – *Acer rubrum*, 8611; *Acer saccharum*, 8741. **17** – *Acer rubrum*, 8612. **24** – *Acer saccharum*, 8977. S5, GNR; frequent (Wong and Brodo 1992).
- **Lecidea sarcogynoides** Körb.: **12** – rock, 9106 (NY). SNR GNR; not reported by Wong and Brodo (1992).
- Lepraria caesiella* R.C. Harris: **8** – *Tsuga canadensis*, 9116 (OAC, NY). **20** – *Abies balsamea*, 9145 (NY). SNR, GNR; frequent (Wong and Brodo 1992).
- Lepraria elobata* Tønsb.: **3** – *Fagus grandifolia*, 9129 (OAC, NY). **8** – *Tsuga canadensis*, 9118 (NY). SU, GNR; not reported by Wong and Brodo (1992).
- Lepraria finkii* (B. de Lesd.) R.C. Harris: **1** – *Picea*, 9134 (NY). **2** – *Betula alleghaniensis*, 9131. **8** – *Thuja occidentalis*, 9121. **13** – *Quercus rubra*, 9251. **16** – *Thuja occidentalis*, 9124. **18** – *Acer saccharum*, 9256. **19** – snag, 9112. S5, GNR; common (Wong and Brodo 1992).
- †*Leptorhaphis epidermidis* (Ach.) Th. Fr.: **4** – *Betula papyrifera*, 8613. S4, GNR; infrequent (Wong and Brodo 1992).
- Megalaria laureri* (Hepp ex Th. Fr.) Hafellner: **19** – *Fagus grandifolia* snag, 9110 (NY, OAC). SNR, GNR; infrequent (Wong and Brodo 1992).
- Melanelia sorediata* (Ach.) Goward & Ahti: **12** – rock, 8617, 8618. S5, GNR; infrequent (Wong and Brodo 1992).
- Melanelixia fuliginosa* (Fr. ex Duby) O. Blanco et al.: **2** – snag, 8614; *Pinus strobus*, 8728. **16** – *Acer rubrum*, 8615, 8616. S3, G5; not reported by Wong and Brodo (1992).
- Melanelixia subaurifera* (Nyl.) O. Blanco et al.: **1** – *Fraxinus americana*, 8884. **3** – deciduous snag, 8823. **6** – snag, 8792. **9** – *Malus*, 8772, 8779, 8869; on *Populus balsamifera*, 8787; *Prunus*, 8805; *Picea glauca*, 8957. **11** – *Acer*, 8781; *Acer saccharum*, 8818. **12** – *Pinus strobus*, 8624; *Rhus typhina*, 8880. **13** – stump, 8942. **16** – *Pinus sylvestris* snag, 8937; *Acer saccharum*, 8876. **24** – *Acer saccharum*, 8985. S5, G3G5; very common (Wong and Brodo 1992).
- **Micarea micrococca** (Körb.) Gams ex Coppins: **8** – snag, 9150 (NY). SNR, GNR; not reported by Wong and Brodo (1992).
- Micarea peliocarpa* (Anzi) Coppins & R. Sant.: **2** – snag, 8619; *Thuja occidentalis* snag, 8620. **16** – *Thuja occidentalis*, 8621. S4S5, G4G5; frequent (Wong and Brodo 1992).
- Micarea* sp.: **16** – wooden fence post, 9157 (NY).
- Multiclavula mucida* (Fr.) R. Petersen: **15** – moist fallen log, 8622. SU, GNR; rare (Wong and Brodo 1992).
- †*Mycocalicium subtile* (Pers.) Szatala: **2** – decorticated snag, 8092, 8096, 9286. **5** – decorticated snag, 8084, 8095. **13** – decorticated snag, 8083, 8088. **16** – decorticated snag, 8069. S4S5, G4G5; infrequent (Wong and Brodo 1992).
- Myelochroa aurulenta* (Tuck.) Elix & Hale: **8** – *Acer saccharum*, 8623, 8625. **17** – *Acer saccharum*, 8742. **22** – *Acer saccharum*, 8976. S5, G5?; common (Wong and Brodo 1992).
- Ochrolechia arborea* (Kreyer) Almb.: **1** – *Quercus rubra*, 9137 (NY). **2** – snag, 8633. **5** – snag, 8850. **6** – snag, 8634. S4S5, GNR; common (Wong and Brodo 1992).
- Pachyphiale fagicola* (Hepp) Zwackh: **1** – *Quercus rubra*, 9136. S1, GNR; very rare (Wong and Brodo 1992).
- Parmelia sulcata* Taylor: **1** – *Fraxinus americana*, 8886. **2** – snag, 8829; deciduous snag, 8838; *Thuja occidentalis* snag, 8873. **3** – deciduous snag, 8825. **6** – snag, 8793. **9** – *Malus*, 8768, 8776, 8868; *Prunus*, 8804; *Fraxinus*, 8832; *Picea glauca*, 8956. **10** – snag, 8952. **11** – *Acer saccharum*, 8817; *Pinus resinosa*, 8947. **12** – *Pinus strobus*, 8635; snag, 8803; *Rhus typhina*, 8881. **13** – *Acer rubrum*, 8636; stump, 8944. **16** – snag, 8637; deciduous snag, 8638; *Pinus sylvestris* snag, 8934. S5, G5; very common (Wong and Brodo 1992).
- Parmeliopsis ambigua* (Wulfen) Nyl.: **12** – snag, 8639; *Rhus typhina* snag, 8640. S5, G3G5; infrequent (Wong and Brodo 1992).

- Parmeliopsis hyperopta* (Ach.) Arnold: **12** – snag, 8743; *Rhus typhina* snag, 8641. S5, G3G5; rare (Wong and Brodo 1992).
- Peltigera didactyla* (With.) J.R. Laundon: **4** – sandy soil, 8744. **19** – sandy soil, 8642. S5, G5; common (Wong and Brodo 1992).
- Peltigera extenuata* (Vain.) Lojka: **4** – sandy soil, 8643, 8644, 8743. Notes: Included with *Peltigera didactyla* in the past. SNR, GNR; see *Peltigera didactyla* in Wong and Brodo (1992).
- Peltigera lepidophora* (Nyl. ex Vain.) Bitter: **4** – sandy soil, 8746. **19** – sandy soil, 8771. **21** – on soil, 8991. S4, G4; frequent (Wong and Brodo 1992).
- Peltigera praetextata* (Flörke ex Sommerf.) Zopf: **8** – base of an *Acer saccharum*, 8645. **19** – decomposing log, 8646; soil, 8747. **24** – base of an *Acer saccharum*, 8987. S5, G3G5; common (Wong and Brodo 1992).
- Peltigera rufescens* (Weiss) Humb.: **4** – sandy soil, 8647, 8648. S5, G5; common (Wong and Brodo 1992).
- Pertusaria macounii* (I.M. Lamb) Dibben: **8** – *Acer saccharum*, 8748, 8799, 9282. **24** – *Acer saccharum*, 8984. S4, G4G5; frequent (Wong and Brodo 1992).
- †*Phaeocalicium curtisii* (Tuck.) Tibell: **1** – *Rhus typhina*, 8082. **2** – *Rhus typhina*, 8101. **9** – *Rhus typhina*, 8061. **12** – *Rhus typhina*, 8067. **16** – *Rhus typhina*, 9247. S5, GNR; common (Wong and Brodo 1992).
- †*Phaeocalicium polyporaеum* (Nyl.) Tibell: **3** – polypore, 8090, 8102. **8** – polypore, 8098. **10** – polypore, 8085. **11** – polypore, 8064. **17** – polypore, 9285. **19** – polypore, 8066. S3, GNR; rare (Wong and Brodo 1992).
- †*Phaeocalicium populneum* (Brond. ex Duby) A.F.W. Schmidt: **9** – *Populus balsamifera*, 8072. SU, GNR; rare (Wong and Brodo 1992).
- Phaeophyscia adiastrata* (Essl.) Essl.: **4** – *Quercus rubra*, 8855. **11** – mossy rock, 8749. S4, G4?; very common (Wong and Brodo 1992).
- Phaeophyscia pusilloides* (Zahlbr.) Essl.: **1** – *Fraxinus*, 8763. **3** – deciduous snag, 8827. **4** – *Quercus rubra*, 8651. **8** – *Acer saccharum*, 8652; snag, 8841; *Abies balsamea*, 8849. 9283. **9** – *Populus balsamifera*, 8750; *Fraxinus*, 8833. **11** – *Acer*, 8859. **16** – *Acer rubrum*, 8653; *Acer saccharum*, 8836. **19** – *Acer*, 8654. S5, G5; common (Wong and Brodo 1992).
- Phaeophyscia rubropulchra* (Degel.) Essl.: **1** – *Fraxinus*, 8795; *Quercus rubra*, 9260. **2** – *Acer*, 8656. **3** – *Acer saccharum*, 8821. **4** – *Quercus rubra*, 8655; *Acer saccharum*, 8657. **8** – *Acer saccharum*, 8658, 8807. **9** – *Malus*, 8870. **13** – *Acer rubrum*, 8659. **16** – *Acer saccharum*, 8835. **17** – *Acer saccharum*, 8839. **24** – *Acer saccharum*, 8978. S5, G5; very common (Wong and Brodo 1992).
- Phlyctis argena* (Spreng.) Flot.: **2** – *Thuja occidentalis* snag, 8674, 8675. **20** – *Thuja occidentalis*, 9226. S4S5, G4G5; infrequent (Wong and Brodo 1992).
- **Phlyctis speirea* G. Merr.: **20** – *Thuja occidentalis*, 8973. SNR, GNR; not reported by Wong and Brodo (1992).
- Physcia adscendens* (Fr.) H. Olivier: **1** – *Fraxinus americana*, 8885. **3** – deciduous snag, 8828. **4** – *Quercus rubra*, 8854. **8** – snag, 8844. **9** – deciduous snag, 8721; *Malus*, 8769, 8778; *Populus balsamifera*, 8786; *Fraxinus*, 8834; *Picea glauca*, 8955. **12** – *Rhus typhina*, 8660. **13** – stump, 8945. **16** – deciduous snag, 8661; *Picea glauca*, 8662. S5, G5; very common (Wong and Brodo 1992).
- Physcia aipolia* (Ehrh. ex Humb.) Fűrnr.: **1** – *Fraxinus*, 8663. **4** – *Quercus rubra*, 8751. **16** – deciduous snag, 8752. S5, G5TNR; very common (Wong and Brodo 1992).
- Physcia dubia* (Hoffm.) Lettau: **16** – rock, 8664. S5, G5; common (Wong and Brodo 1992).
- Physcia millegrana* Degel.: **1** – *Quercus rubra*, 9259; *Fraxinus*, 8665. **3** – deciduous snag, 8824. **4** – *Quercus rubra*, 8856. **8** – a deciduous snag, 8882; *Acer saccharum*, 8666. **9** – *Prunus*, 8806; *Malus*, 8766, 8775; deciduous snag, 8758. **10** – snag, 8950. **11** – *Acer saccharum*, 8875; *Acer*, 8667. **13** – *Acer rubrum*, 8668; *Picea glauca*, 8727. **16** – *Acer saccharum*, 8815. **22** – on *Acer saccharum*, 8983. **24** – *Acer saccharum*, 8988. S5, G5; very common (Wong and Brodo 1992).
- Physcia stellaris* (L.) Nyl.: **9** – *Populus balsamifera*, 8669; *Populus grandidentata*, 8753; *Malus*, 8780. **11** – *Acer saccharum*, 8816. S5, G5; very common (Wong and Brodo 1992).
- Physconia detera* (Nyl.) Poelt: **9** – deciduous snag, 8757; *Fraxinus*, 8831. **16** – *Acer saccharum*, 8670, 8754. S5, G5?; very common (Wong and Brodo 1992).
- Physconia enteroxantha* (Nyl.) Poelt: **1** – *Fraxinus*, 8673. **8** – *Acer saccharum*, 8671, 8808. **13** – *Acer rubrum*, 8672. S3, G3G5; infrequent (Wong and Brodo 1992).
- Placynthiella uliginosa* (Schr.) Coppins & P. James: **12** – sandy soil, 8676. S2, G5; rare (Wong and Brodo 1992).
- Porpidia cinereoatra* (Ach.) Hertel & Knoph: **18** – rock, 8755. S1S3, G5?; not reported by Wong and Brodo (1992).
- Porpidia crustulata* (Ach.) Hertel & Knoph: **10** – rock, 9128 (NY). S5, G4G5; common (Wong and Brodo 1992).
- Porpidia macrocarpa* (DC.) Hertel & A.J. Schwab: **7** – rock, 9156 (NY). **12** – rock, 9109 (NY, OAC). S4, G4; frequent (Wong and Brodo 1992).
- Protoblastenia rupestris* (Scop.) J. Steiner: **2** – cement culvert over water, 9130 (NY, OAC). S5, G4G5; common (Wong and Brodo 1992).

- Protoparmelia hypotremella* Herk, Spier & V. Wirth: **20** – decorticated *Thuja occidentalis* branch, 9228. SNR, GNR; not reported by Wong and Brodo (1992).
- Punctelia rudecta* (Ach.) Krog: **1** – *Quercus rubra*, 9261. **2** – *Thuja occidentalis* snags, 8677, 8678, 8872. **8** – *Acer saccharum*, 8679, 8680; *Thuja occidentalis*, 8865. **9** – deciduous snag, 8759; snag, 9219. **10** – *Thuja occidentalis*, 8681. **13** – *Picea glauca*, 8726. **16** – *Acer*, 8782; snag, 8861. **20** – *Thuja occidentalis*, 8864. **22** – *Acer saccharum*, 8989. **24** – *Acer saccharum*, 8981. S5, G5; very common (Wong and Brodo 1992).
- Pyxine sorediata* (Ach.) Mont.: **8** – *Acer saccharum*, 8682. S5, G5, common (Wong and Brodo 1992).
- Ramalina intermedia* (Delise ex Nyl.) Nyl.: **2** – *Thuja occidentalis* snag, 8683. **9** – snag, 9222. S5, G4G5; common (Wong and Brodo 1992). *Rinodina tephrae* (Tuck.) Herre: **10** – granitic rock, 9127 (NY). S4, GNR; frequent (Wong and Brodo 1992).
- Ropalospora viridis* (Tønsb.) Tønsb.: **16** – *Populus tremuloides*, 9125 (NY, OAC). **17** – snag, 9143 (NY, OAC). SNR, GNR; not reported by Wong and Brodo (1992).
- Sarcogyne hypophaea* (Nyl.) Arnold: **9** – siliceous rock, 8819. SU, G2G4; infrequent (Wong and Brodo 1992).
- Sarcogyne regularis* Körb.: **12** – calcareous rock, 8684. S5, G5; common (Wong and Brodo 1992).
- Scoliciosporum chlorococcum* (Stenh.) Vězda: **12** – *Rhus typhina*, 8879. S5, G4G5; very common (Wong and Brodo 1992).
- †*Sphinctrina anglica* Nyl.: **20** – decorticated *Thuja occidentalis* branch, 9227. S3, GNR; rare (Wong and Brodo 1992).
- †*Stenocybe major* (Nyl.) Körb.: **13** – *Abies balsamea*, 8079. S2S3, G4; rare (Wong and Brodo 1992).
- †*Stenocybe pullatula* (Ach.) Stein: **2** – *Alnus incana* ssp. *rugosa*, 8081. **8** – *Alnus incana* ssp. *rugosa*, 8099. **9** – *Alnus incana* ssp. *rugosa*, 8065, 8097. **13** – *Alnus incana* ssp. *rugosa*, 8089, 8100. **16** – *Alnus incana* ssp. *rugosa*, 8063. SU, GNR; rare (Wong and Brodo 1992).
- Stereocaulon saxatile* H. Magn.: **12** – granitic rock, 8685. S5, G5; common (Wong and Brodo 1992).
- Stereocaulon tomentosum* Fr.: **12** – soil, 8686. S4S5, G5; rare (Wong and Brodo 1992).
- Trapelia placodioides* Coppins & P. James: **12** – rock, 9108 (NY). S5, GNR; common (Wong and Brodo 1992).
- Trapeliopsis flexuosa* (Fr.) Coppins & P. James: **13** – lignicolous stump, 8687. S4S5, G5; frequent (Wong and Brodo 1992).
- Trapeliopsis granulosa* (Hoffm.) Lumbsch: **12** – sandy soil, 8688. S5, GNR; common (Wong and Brodo 1992).
- Usnea hirta* (L.) F.H. Wigg.: **11** – *Pinus resinosa*, 8946. **12** – *Rhus typhina*, 8756. S4S5, G3G5; frequent (Wong and Brodo 1992).
- Usnea subfloridana* Stirt.: **9** – deciduous snag, 8974. **12** – snag, 8999. S4S5, GNR; rare (Wong and Brodo 1992).
- Variolaria amara* Ach.: **2** – snag, 8649. **8** – *Thuja occidentalis*, 9253. **9** – snag, 9221. **20** – *Thuja occidentalis*, 8650. S4S5, G5?; frequent (Wong and Brodo 1992).
- Verrucaria* sp.: **12** – rock, 9107 (NY, OAC).
- Violella fucata* (Stirt.) T. Sprib. **2** – snag, 9152 (NY). SNR, GNR; not reported by Wong and Brodo (1992).
- Vulpicida pinastri* (Scop.) J.-E. Mattsson & M.J. Lai: **12** – *Rhus typhina* snag, 8689. S4S5, G4G5; rare (Wong and Brodo 1992).
- Xanthomendoza fallax* (Hepp ex Arnold) Søchting, Kärnefelt & S. Kondr.: **1** – *Quercus rubra*, 8696, 8697. S5, G5; very common (Wong and Brodo 1992).
- Xanthomendoza ulophyllodes* (Räsänen) Søchting, Kärnefelt & S. Kondr.: **8** – *Abies balsamea*, 8791. SNR, GNR; not reported by Wong and Brodo (1992).
- **Xanthoparmelia angustiphylla* (Gyelnik) Hale: **9** – rock, 9000. S1, G5; not reported by Wong and Brodo (1992).
- Xanthoparmelia cumberlandia* (Gyeln.) Hale: **9** – siliceous rock, 8691. **10** – siliceous rock, 8692. **12** – siliceous rock, 8693–8695, 8761. **16** – siliceous rock, 8773. S5, G5; very common (Wong and Brodo 1992).
- Xanthoparmelia viriduloumbrina* (Gyelnik) Lendemer: **12** – rock, 8698. SNA, G5; common (Wong and Brodo 1992).
- Xanthoria polycarpa* (Hoffm.) Th. Fr. ex Rieber: **9** – *Picea glauca*, 8760; *Populus balsamifera*, 8785. S4, G4G5; frequent (Wong and Brodo 1992).

Discussion

The Copeland Forest Resources Management Area is a refuge for lichen diversity in southern Ontario. The forest contains 129 (28%) of the 465 species reported from the region by Wong and Brodo (1992), as well as an additional 25 species that were not on that list. This is despite the fact that the study area hosts only a small percentage of the variety of ecosystems that occur across the southern part of the province.

Two other extensive lichen diversity studies have been completed in specific regions of southern Ontario. The first study was in the Ottawa region, where 277 species were found on the Ontario side of the Ontario/Quebec border (Brodo 1988). The second study was at Bruce Peninsula National Park of Canada and Fathom Five National Marine Park of Canada, where the 17th Tuckerman Workshop was held in 2008. A team of lichenologists at the workshop reported 365 species

of lichens and allied fungi (Brodo *et al.*, in press). The lichen richness in both of these studies is higher than in the Copeland Forest, but both areas have a greater number of ecosystems, which can be colonized by a greater number of species. The lichen richness found in these studies and in the Copeland Forest are not comparable because of the ecological differences and the substantially different degrees of disturbance.

Wong and Brodo (1992) found that 51 lichen species previously recorded from the province were no longer present. They hypothesized that this was due to a decline in air quality, an increase in development, and a loss of habitat. The Copeland Forest exemplifies this apparent decline in species richness, as no species typically used as indicators of good air quality were found (Henderson 2000; Cameron *et al.* 2007; McMullin and Ure 2008). Particular species that were notably absent in the Copeland Forest were those that contain cyanobacteria (cyanolichens). No cyanolichens were present, with the exception of the genus *Peltigera*, which is common even in disturbed areas.

The Copeland Forest Resources Management Area is a relatively large continuous woodland in southern Ontario. Many of the forests that remain in southern Ontario, particularly those in the southwestern part of the province, are fragmented. Fragmentation has been shown to reduce the diversity in species communities (Fahrig 2003). One of the reasons for this reduction is an increase in edge effects, which include an increase in light and wind exposure as well as a reduction in moisture compared with the forest interior (Chen *et al.* 1993; Renhorn *et al.* 1997; Esseen and Renhorn 1998). The Copeland Forest is large enough (1780 ha) to contain a significant forest interior, which includes many microhabitats for lichens to colonize.

Old-growth forests have been shown to have a greater lichen diversity because they contain a greater number of microhabitats than second-growth forests of the same area (Lesica *et al.* 1991; McMullin *et al.* 2008), but Löhmus and Löhmus (2011) recently showed that managed second-growth forests that cover a large area can also contain a wide variety of microhabitats and, therefore, a wide variety of species. The overall lichen diversity of the study area exemplifies the findings of Löhmus and Löhmus (2011). In other words, its large area contains a number of different microhabitats that support a wide variety of lichen communities, despite heavy recreational use and recent silvicultural disturbance.

Within the context of the study area, the alpha diversity in each of the 24 sites examined also differed considerably. The 6 sites with the highest lichen richness also had unique assemblages of species which helped to increase the overall number of species in the study area. Site 2 had the highest number of species (42). This site is in a protected river valley with a variety of mature trees along the valley slopes and exposed trees and snags in the floodplain of the Coldwater Riv-

er. Moisture was high and sustained at this site, and the trees appeared to be older than most in the study area; this may be an area that was not harvested in the past.

Site 12 had the second highest number of species (40). This site contains an exposed area of rolling hills covered in sandy soil; it also contains the highest lichen biomass in the Copeland Forest, as the ground cover is dominated by species in the genus *Cladonia* subgenus *Cladina*. This exposed area is sheltered by the surrounding forest and contains exposed calcareous rocks, which are rare in the study area, where most rocks are siliceous.

Two similar sites with high diversity were 16 (40 species) and 8 (37 species). Both of these sites were large tracts of uninterrupted mixed hardwood forests with water bodies in close proximity, which presumably maintain high and sustained levels of moisture. Site 9 (38 species) was along the same river that runs through site 2. Where the Coldwater River runs through site 9, however, it is not in a sheltered area and there is no floodplain with snags or trees. The microhabitats at this site include a variety of exposed trees, exposed rocks, and exposed cement on a river culvert. Site 13 (33 species) is a treed wetland with high light exposure and high levels of moisture that are sustained.

These 6 sites were the only ones of the 24 that contained more than 30 species each. Common variables among these sites included high light exposure and a variety of tree types, and moisture was generally higher. Many of the other sites have closed canopies, which may have limited the number of species able to colonize (Coxson and Coyle 2003; Coxson and Stevenson 2007).

These results are consistent with a recent study by McMullin *et al.* (2010), which showed that variation in light (canopy closure), moisture, soil, and tree types and ages were the primary environmental variables driving lichen diversity in forest ecosystems. Because of the variation in these sites, the lichen community structure in them differed. When combined, they increased the gamma diversity in the Copeland to a number much higher than any one site contained. Once again, these results support the species-area correlation described by Löhmus and Löhmus (2011).

This study contributes to a growing body of knowledge of the lichen biota in southern Ontario. The number of species now known from the southern region of the province has increased substantially since the account of Wong and Brodo (1992) (Matthes *et al.* 2000; Selva 2005; Brodo *et al.*, in preparation; McMullin and Lewis, in preparation; Lewis *et al.*, in preparation). Based on this study, provincial status ranks, the status given by Wong and Brodo (1992), the results from the lichen study on the Bruce Peninsula (Brodo *et al.*, in preparation), and unpublished collections from southern Ontario (in the Lichenology Section of the National Herbarium of Canada, Canadian

Museum of Nature, Ottawa, Ontario (CANL), in the Botany Department Herbarium, University of Guelph, Guelph, Ontario (OAC), and NY), the following lichen species are identified as species of interest in the Copeland Forest Resource Management Area: *Anisomeridium polypori*, *Arthonia byssacea*, *A. ruana*, *Bellemerea cinereorufescens*, *Calicium trabinellum*, *Candelariella lutella*, *Chaenothecopsis debilis*, *Chaenothecopsis exilis*, *Chaenothecopsis pusiola*, *Cladonia digitata*, *Cladonia parasitica*, *Cresponea chloroconia*, *Lecidea sarcogynoides*, *Micarea micrococca*, *Multiclavula mucida*, *Pachyphiale fagicola*, *Parmeliopsis hyperopta*, *Phaeocalicium populneum*, *Phlyctis speirea*, *Placynthiella uliginosa*, *Porpidia cinereoatra*, *Stereocaulon tomentosum*, *Vulpicida pinastri*, and *Xanthoparmelia angustiphylla*. These species appear to be uncommon in Canada, Ontario, or southern Ontario. *Pachyphiale fagicola* is the only species reported that seems to be rare throughout its known range (Vězda and Poelt 1975; Ekman 1996). It is, however, a small and inconspicuous species that may be overlooked. *Lecidea sarcogynoides* is another seemingly rare species in North America. It is known from only one other unreported collection in North America, from Pennsylvania in 2008 (Lendemer 12598, NY), but it may have been overlooked in the past as well.

Micarea micrococca is collected and reported for the first time from Ontario, but it was only recently separated from *M. prasina* s.l. based on chemistry (Czarnota 2007; Czarnota and Guzow-Krzemińska 2010). This somewhat inconspicuous species is known from three neighbouring states in the United States, Michigan (*Common* 3344, at the Plant Biology Laboratories Herbarium, Michigan State University, East Lansing, Michigan (MSC)), New York (*Common* 3990, MSC), and Pennsylvania (Lendemer 16665, NY), so it is not surprising that it was found in Ontario.

Micarea micrococca is also reported for the first time in Canada, but three previous collections were made in 2008 in Newfoundland, Newfoundland and Labrador (Buck 944316, 944317, NY, and Lendemer 10093, NY).

Three additional species are reported for the first time in Ontario, but have been previously collected in the province—*Bellemerea cinereorufescens*, *Phlyctis speirea*, and *Xanthoparmelia angustiphylla*. *Bellemerea cinereorufescens* is collected for the third time in Ontario. It is typically an arctic and alpine species, so this range extension into southern Ontario is surprising (Figure 2C) (Thomson 1997). It was first collected in the province from the Thunder Bay District in 1968 (Brodo 19705, CANL) and again in 1991 in Renfrew County in eastern Ontario (Brodo 27914, CANL). *Phlyctis speirea* was first collected from southern Ontario in 2010 (Lewis 392, CANL). *Xanthoparmelia angustiphylla* is known from New England and Minnesota (Wetmore 2005; Hinds and Hinds 2007), so it is not surprising that it was found in Ontario. The

first collection of *X. angustiphylla* in the province is from 1983 in northern Ontario (Fischlin 160, CANL). Two other seemingly rare species in Ontario that were collected in the Copeland Forest are *Candelariella lutella* and *Chaenothecopsis exilis*. *Candelariella lutella* is reported and collected for the second time in Ontario and the third time in Canada (Thomson 1997). *Chaenothecopsis exilis* was previously collected and reported from northeastern Ontario (McMullin 2011) and from the north shore of Lake Superior (Tibell 5389, Botany Section, Museum of Evolution, Uppsala University, Uppsala, Sweden (UPS)) (Selva and Tibell 1999).

Ten species with a provincial status rank of S1 (imperilled), S2 (imperilled), or S3 (vulnerable) were found in the Copeland Forest. Due to the lack of baseline data on the lichen biota in the province in the past, some of these ranks may no longer be accurate because of additional recent collections. Based on the results of the present study and recent collections made throughout Ontario, we recommend that the following species be reassessed and moved to a higher provincial rank: *Chaenothecopsis pusiola*, *Cresponea chloroconia*, *Placynthiella uliginosa*, *Anisomeridium polypori*, *Chaenothecopsis debilis*, *Porpidia cinereoatra*, *Stenocybe major*.

Conclusion

Lichen richness in the Copeland Forest Resources Management Area is high, and the site serves as a refuge for lichen diversity in southern Ontario, where lichen richness has been decreasing for more than a century (Wong and Brodo 1992). Our study has shown not only that this forest has potential conservation significance, but also that second-growth forests in general can support a diverse lichen biota in the province. While our results cannot *a priori* be extrapolated to secondary forests as a whole, they do indicate that large tracts of such forests merit study and consideration for the conservation and management of lichen biodiversity.

Future management plans for the Copeland Forest should include the preservation of lichen diversity and should target the sites with the greatest richness (sites 2, 8, 9, 12, 13, and 16). Such plans should also specifically target uncommon species. If a single site is to be selected for protection in the Copeland Forest, site 12 is recommended. This site has a unique lichen community that includes many of the species of interest from this study and the only species that is new to Canada, *Lecidea sarcogynoides*. Site 1 is also recommended because it contains *Pachyphiale fagicola*, one of the only species found in the Copeland Forest that appears to be rare throughout its range.

The results from our study contribute to a better understanding of the understudied lichen biota of southern Ontario, particularly in second-growth forests. Most intensive lichen studies in the region have been in protected areas, such as national and provincial parks,

in older and less disturbed forests (Matthes *et al.* 2000; Selva 2005; Brodo *et al.*, in press; McMullin and Lewis, in press; Lewis *et al.*, in preparation). These older forests are uncommon in southern Ontario, and younger second-growth forests that are intensively used now dominate the natural landscape.

Here we have shown that second-growth forests can be important refugia for lichen diversity. We found that sites with a high variation in canopy closure, tree species and age (particularly different deciduous and conifer trees), moisture, and the presence of snags have the highest lichen diversity. Forest managers in southern Ontario interested in preserving lichen diversity can use our results to help identify and protect areas of interest on their properties.

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Home Site Fidelity in Black Rockfish, *Sebastes melanops*, Reintroduced into a Fjord Environment

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Between December 2004 and January 2007, we studied the movements of six Black Rockfish (*Sebastes melanops*) that had been fitted with acoustic transmitters and reintroduced into a fjord environment at the edge of Vancouver Harbour, British Columbia. The Black Rockfish were released in December 2004 and April 2005 at a reef characterized by complex rocky structures and steep slopes; bottom depths at the site dropped from 10 to 55 m within a horizontal distance of only 30 m. The reef, however, is small (approximately 4500 m²) and is surrounded by soft bottom habitats used infrequently by Black Rockfish. VEMCO VR2 receivers were deployed at the release site and at outlying reefs located 1 and 4 km away. Acoustic data suggest that one individual emigrated from the reef after 11 months of residency and a second individual disappeared abruptly after 6 weeks on the reef, possibly due to fishing mortality or emigration. The four remaining individuals appear to have confined their movements to the release site, using an area 6 to 10 times smaller than the home ranges reported for populations in low-gradient coastlines in California and Oregon.

Key Words: acoustic transmitters; animal movement; animal reintroductions; Black Rockfish; *Sebastes melanops*; ecological restoration; habitat effects on movement; home site fidelity; British Columbia

Introduction

Rockfishes (*Sebastes* spp.) are vulnerable to over-exploitation (Love et al. 2002; Berkeley et al. 2004), and data on their movements and home site fidelity are important for managing the genus (Freiwald 2012). For instance, whether networks of marine reserves succeed in restoring exploited populations may depend on the extent to which dispersing juveniles and resident adults confine their movements to protected areas (Moffitt et al. 2009).

For some rockfish species, the distances moved by adults may depend on habitat. The home ranges of Copper Rockfish (*Sebastes caurinus*) and Quillback Rockfish (*S. maliger*), for example, span less than 30 m² in structurally complex boulder piles (Matthews 1990a, 1990b) but cover 1.5 to 2.5 km² in simpler substrates, such as low-relief sandstone composite (Tolimieri et al. 2009). These patterns are potentially explained by the higher density of refuges and perhaps greater prey abundance in the more complex habitats (Frid and Marliave 2010).

In Black Rockfish (*Sebastes melanops*) populations, some adults emigrate several hundred kilometres from the sites where they were tagged, but most individuals remain near their tagging locations (Green and Starr 2011 and references within). In low-gradient coastlines of California and Oregon, where Black Rockfish in shallow habitats (10 m bottom depths) must move horizontally 0.5 to >1 km to reach deeper habitats (>20 m bottom depths), adult home ranges averaged 0.25 km² in California (Green and Starr 2011) and 0.55 km² in Oregon (Parker et al. 2007).

Use of space by Black Rockfish in fjords, where bottom depths drop from shallow to deep habitats within a few horizontal metres, is poorly understood. We hypothesized that, in this environment, Black Rockfish would confine their movements to habitat patches much smaller than the home ranges reported for individuals in low-gradient coastlines.

We tested this hypothesis during a restoration project in which Black Rockfish were surgically implanted with acoustic transmitters and transplanted from the west coast of Vancouver Island to Point Atkinson, a fjord environment at the edge of Vancouver Harbour, British Columbia (Figure 1). Point Atkinson is suitable for testing our hypothesis: at that site, rocky habitat preferred by rockfish (Love et al. 2002) encompasses only 4500 m² and is surrounded by soft substrates, which Black Rockfish use infrequently (Johnson et al. 2003). Additionally, bottom depths at the Point Atkinson reef drop from 10 m to 55 m within a horizontal distance of only 30 m (Figure 2). Copper Rockfish and Quillback Rockfish are common species on rocky habitats of the area and occur at the three study reefs (JM, unpublished data), indicating that these sites provide suitable habitats for benthic-dwelling rockfishes.

Study Site and Methods

Our acoustic transmitter project was the final stage in transplanting a 1996 cohort of Black Rockfish from the west coast of Vancouver Island to the east side of Point Atkinson, British Columbia (Figure 1). Point Atkinson is a popular sport angling reef where Black Rockfish had been depleted. Diving biologists docu-

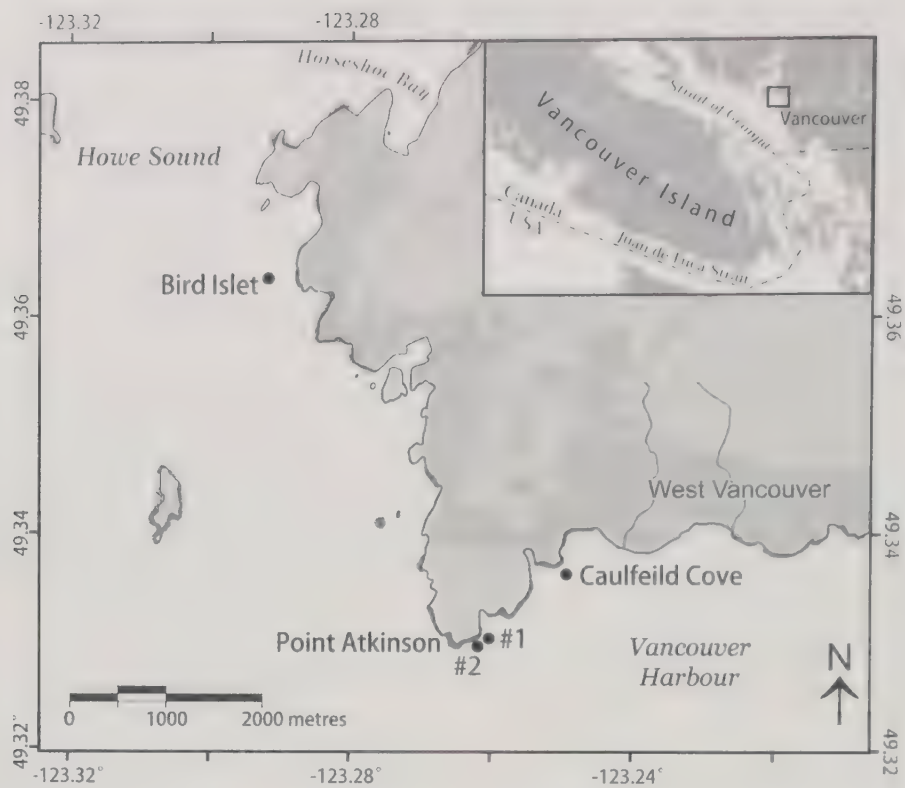


FIGURE 1. Map of the study site at Point Atkinson, British Columbia. Filled circles at Bird Islet, Point Atkinson, and Caulfeild Cove indicate receiver locations.

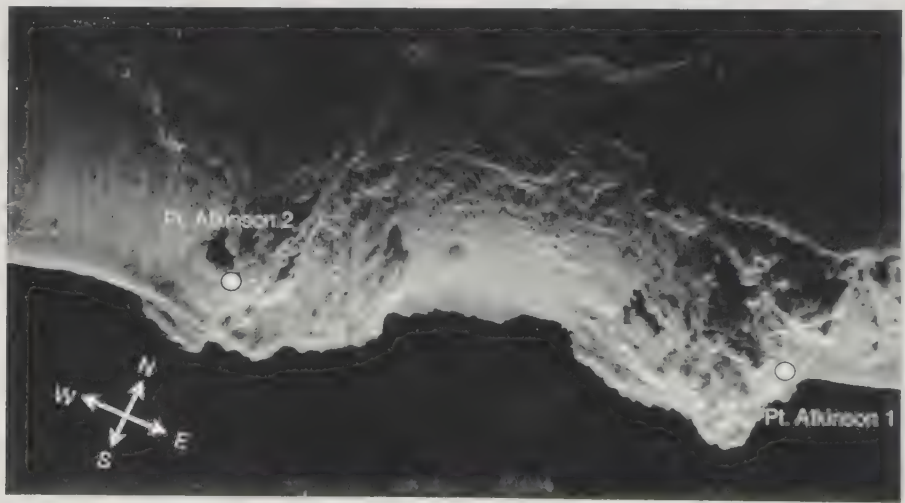


FIGURE 2. Sidescan sonar image of the Point Atkinson reef and VR2 receivers, as seen from the surface looking down at the reef. Bottom depths drop from shallowest at the top to deepest at the bottom of the image. Due to a “shadow” in sonar reading, depths deeper than 33 m (which encompass boulder habitat) appear as a black band at the bottom of the image. Receivers were approximately 45 m apart; the portion of reef depicted is $\approx 2300\text{ m}^2$.

mented schools of Black Rockfish at the site in the 1960s, but noted the species’ absence by the early 1970s (Andy Lamb, personal communication). The disappearance of Black Rockfish from Point Atkinson likely coincided with the wider extirpation of the species throughout Vancouver Harbour and adjacent areas in Howe Sound. As described earlier, suitable rocky habi-

tat at Point Atkinson is confined to a 4500 m^2 reef with a steep depth gradient (Figure 2). Black Rockfish were captured as young-of-the-year in Ucluelet, British Columbia, in 1996 and reared at the Vancouver Aquarium. On November 6, 1997, staff from the Washington Department of Fish and Wildlife tagged 252 of these Black Rockfish with coded wire

tags (NMT INC Northwest Marine Technology, Shaw Island, Washington, USA); these yearlings were released at the east side of Point Atkinson between November 1997 and January 1998. Observations by divers after the initial releases suggested that some transplanted fish established residence in the structurally complex rocky reef of Point Atkinson (JM, personal observations). In response to these findings, in June 1998 Fisheries and Oceans Canada temporarily created at that site a small protected area (100m × 80m) where fishing was prohibited.

A subset of Black Rockfish from the 1996 cohort was reared to sexual maturity at the Vancouver Aquarium. VEMCO acoustic transmitters (VEMCO, Bedford, Nova Scotia) were implanted in the abdominal cavities of 4 of these Black Rockfishes on 14 November 2004 and 6 of these Black Rockfishes on 22 March 2005 (total 10) (Table 1). Transmitter size varied according to fish size (Table 1).

Surgical implantation was performed at the Vancouver Aquarium. Tetracycline was administered using a hypodermic syringe a day before surgery and at the time of surgery. A preoperative anaesthetic of metomidate hydrochloride (Aquacalm, Western Chemical Inc., Ferndale, Washington) (10 minutes at 1 mg/L) was followed by full anaesthesia in tricaine methane sulfonate (MS222, 8 minutes at 70 mg/L). Surgical implantation of the transmitters was performed while recirculated, aerated seawater with a low dose level (50 mg/L) of MS222 was pumped over the gills. Incisions were closed with two dissolving sutures of Ethicon PDS-II 2-0 monofilament polydioxanone with an FS-2 cutting needle (Ethicon, Somerville, New Jersey), and fish were then isolated in a dark recovery tank.

After three to five weeks of surgical recovery (Table 1), the Black Rockfish with surgically implanted transmitters were transported under light MS222 anaesthesia (25 mg/L) in aerated seawater to Point Atkinson and placed inside a custom-made 1 m³ zippered cage that divers had tethered at a depth of 18 m near the Point Atkinson release site 1 (Figure 1). Fish were acclimated within the cage for 4–6 days prior to their release (Table 1). During the acclimation period, Sunflower Seastars (*Pycnopodia helianthoides*) killed 4 Black Rockfish through the cage meshes, reducing the sample size to 6 fish with surgical implants (Table 1). Three Black Rockfish were released in December 2004 and 3 were released in April 2005.

Four VEMCO VR2 acoustic receivers (VEMCO, Bedford, Nova Scotia) were deployed at the study area: two at opposite ends of the Point Atkinson reef (approximately 45 m apart) where submarine peaks blocked the line of sight between receivers (Figure 2), one at the Bird Islet rocky reefs, 4 km northwest of Point Atkinson, and one at the Caulfeild Cove reef, 1 km northeast of Point Atkinson (Figure 1 and Table 2). Scuba divers chained the receivers to the bottom and attached under-

TABLE 1. Sample sizes, dates, and transmitter characteristics of the acoustic transmitter project at Point Atkinson, British Columbia. Field acclimation occurred in a cage moored at a depth of 18 m. Start of liberty indicates release from this cage. Transmitter number is in parentheses.

Implant date	No. of Black Rockfish surgically implanted with acoustic transmitters	Fish total length (cm)	Model no.	Transmitter			Start of field acclimation	Start of liberty	No. of Black Rockfish that survived to start of liberty**
				Length (mm)	Average transmission interval (seconds)	Expected battery life (days)*			
14 November 2004	4	42 to 44	V16-5H	92	55	425	8 December 2004	13 December 2004	3 (146, 164, 168)
22 March 2005	3	30 to 40	V13-IH	36	120	215	12 April 2005	18 April 2005	2 (320, 3218)
22 March 2005	3	30 to 40	V13-IH	36	120	215	25 April 2005	29 April 2005	1 (3216)

* Battery life is as estimated by VEMCO, the manufacturer.
** Sunflower Seastars killed Black Rockfish through the cage mesh during acclimation periods.

TABLE 2. Deployment periods for acoustic receivers at Caulfeild Cove, Point Atkinson (release site was Point Atkinson 1), and Bird Islet, British Columbia. Note that receivers VR2 4666, VR2 4667, and VR2 4669 were deployed at different sites during different dates. See Figure 1 for site locations.

Site	Depth (m)	Receiver ID	Date deployed	Date data recovered
Caulfeild Cove	9	VR2 4666	23 December 2004	3 February 2005
		VR2 4666	7 April 2005	27 July 2005
		VR2 4666	8 September 2005	14 March 2006
Point Atkinson 1	30	VR2 4668	22 December 2004	3 February 2005
		VR2 4668	7 April 2005	29 June 2005
		VR2 4668	23 August 2005	6 April 2006*
Point Atkinson 2	17	VR2 4667	5 October 2006	31 January 2007
		VR2 4667	7 January 2005	3 February 2005
		VR2 4667	18 April 2005	29 June 2005
		VR2 4667	10 August 2005	5 April 2006**
Bird Islet	19	VR2 4669	25 April 2006	16 August 2006
		VR2 4666	5 October 2006	29 January 2007
		VR2 4669	6 January 2005	3 February 2005
		VR2 4669	18 April 2005	27 July 2005
		VR2 4669	8 September 2005	14 March 2006

* Memory filled prior to data recovery on 13 December 2005.
**Memory filled prior to data recovery on 31 October 2005.

water mooring buoys which kept receivers 3 m above the bottom.

Data from receivers at Point Atkinson were downloaded four or five times between December 2004 and January 2007. Receivers were out of the water for periods of several weeks during each data download (Table 2). Additionally, computer memory for the Point Atkinson receivers filled to capacity during fall 2005; these receivers did not resume recording until after they had been serviced in the spring of 2006. Receivers located at Bird Islet and Caulfeild Cove operated from December 2005 through March 2006 with three recovery periods for data download (Table 2).

Results

We recorded a total of 1 519 367 detections of 6 Black Rockfish over the cumulative duration of receiver de-

ployments (see Table 2). All detections were confined to the two detection sites located at Point Atkinson; no signals from the 6 Black Rockfish with surgically implanted acoustic transmitters were detected at the outlying locations of Bird Islet or Caulfeild Cove (Figure 1).

Four of the 6 Black Rockfish with surgically implanted acoustic transmitters were detected almost continuously during the periods in which transmitter batteries were expected to be operational and receivers were deployed and had memory space available (Figure 3). (Two Black Rockfish, transmitter numbers 3218 and 3216, were detected for 15 months beyond the expected battery life, but such extended battery life is not predictable and is not guaranteed by the manufacturer.) One Black Rockfish (transmitter number 168) disappeared after only 6 weeks at liberty. A second Black

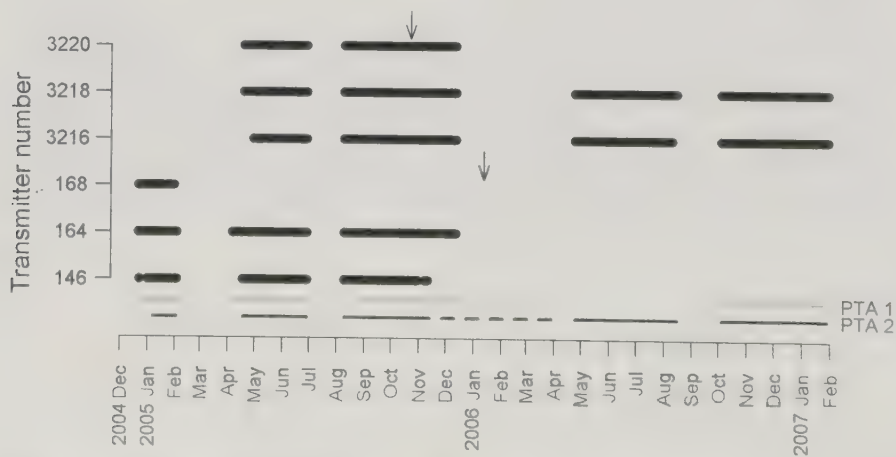


FIGURE 3. Presence and absence of Black Rockfish (*Sebastes melanops*) with surgically implanted acoustic transmitters detected by the two receivers at Point Atkinson, British Columbia (data are combined). Thin lines at the bottom of the graph indicate the periods during which receivers were deployed; dotted lines indicate periods when the memory was full (i.e., unable to collect data). The vertical arrows indicate the expected end of transmitter battery life (see Table 1). The top arrow applies to the first three transmitters and the bottom arrow applies to the last three transmitters.

Rockfish (transmitter number 146) was last detected in mid-November 2005, after 11 months of residency (Figure 3).

The median time between detections ranged from 0.6 to 1.8 minutes (data for all Black Rockfish pooled). Only 138 detections (<0.01%) were spaced by more than an hour; most of these cases may have resulted from Black Rockfish hiding inside crevices where signals were blocked. The longest absences (5 absences of >20 hours) were for Black Rockfish transmitter number 146 at the start and finish of its data set, suggesting that this Black Rockfish undertook excursions away from the release site at the start of liberty, then settled at the reef for 11 months before emigrating (Figure 4). The possibility of emigration is consistent with the fact that detections of signals from Black Rockfish transmitter number 146 ended earlier than detections of signals from Black Rockfish transmitter number 164 (both transmitters were deployed simultaneously and under equal conditions of battery life and receiver availability) (Figure 3).

We assumed that acoustic signals emanated from live Black Rockfish, rather than from transmitters immobile on the bottom. Accordingly, we found that at Point Atkinson—where rocky structures (Figure 2) created acoustic barriers between receivers—the number of daily detections showed patterns consistent with reef-scale movements. Daily detections were highly

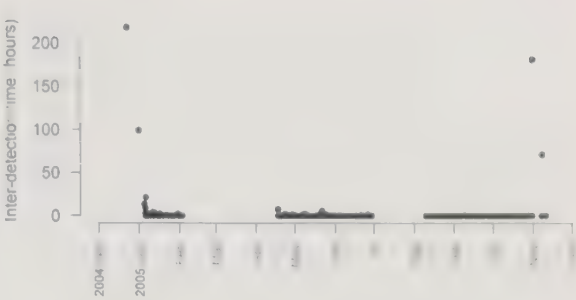


FIGURE 4. Time between detections for Black Rockfish (*Sebastes melanops*) transmitter number 146 with a surgically implanted acoustic transmitter at Point Atkinson, British Columbia.

variable; for some Black Rockfish, detections were at times more numerous at one receiver than the other, and this pattern reversed between receivers over periods of days or weeks (Figures 5 and 6). Although changes in the acoustic environment may have contributed to this variability, we interpret these patterns as evidence of Black Rockfish moving between positions where the rugged terrain would interfere with signal transmission to one or both receivers. This interpretation is consistent with direct observations of live Black Rockfish made by divers at Point Atkinson during the study (JM, personal observations).

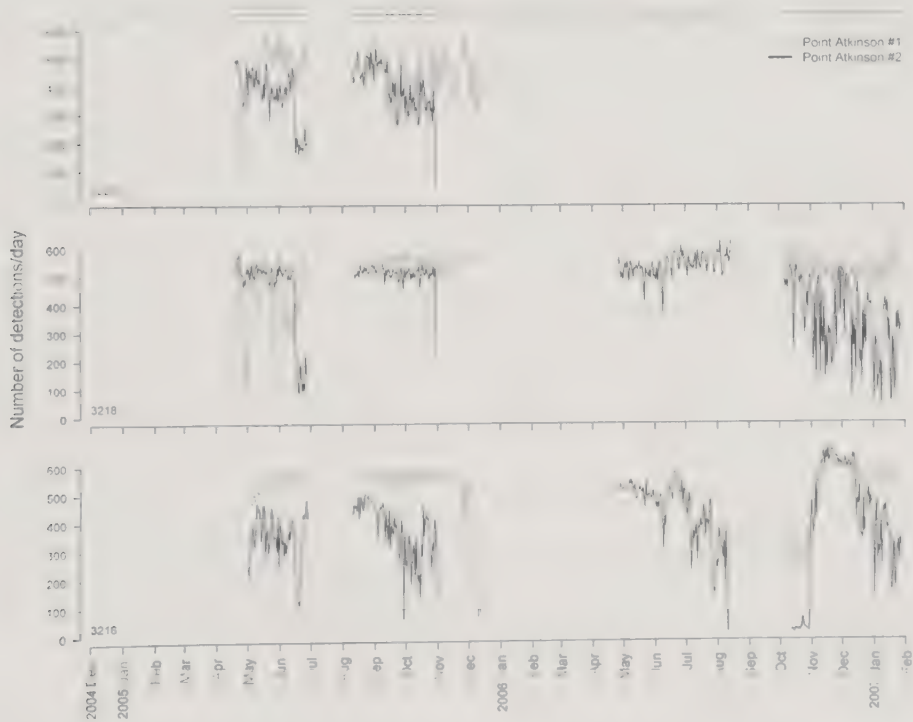


FIGURE 5. Daily number of detections made by receivers no. 1 (grey line) and no. 2 (black line) at Point Atkinson, British Columbia, of signals from Black Rockfish (*Sebastes melanops*) with surgically implanted acoustic transmitters that began liberty during December 2004. The transmitter numbers of the individual Black Rockfish are in the lower left corner. Horizontal lines at the top of the graph indicate the periods during which receivers were deployed; dotted lines indicate periods when the memory was full (i.e., unable to collect data).

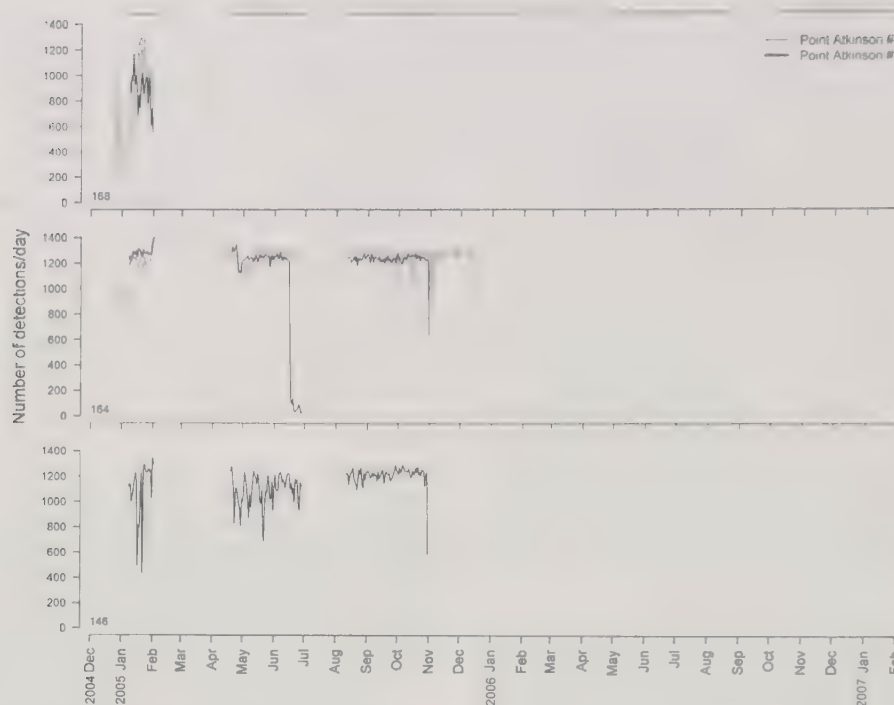


FIGURE 6. Daily number of detections made by Point Atkinson receivers no. 1 (grey line) and no. 2 (black line) of signals from Black Rockfish (*Sebastes melanops*) with surgically implanted acoustic transmitters that began liberty during April 2005. See Figure 5 for details.

Discussion

To our knowledge, this is the first study to report home site fidelity in Black Rockfish with surgically implanted acoustic transmitters in a fjord environment. Our results suggest that 4 of 6 individuals confined their movements to a small rocky reef that spanned only approximately 4500 m². Signals from these Black Rockfish with surgically implanted acoustic transmitters were recorded exclusively and almost continuously at the Point Atkinson reef throughout the period of expected battery life of the transmitters and whenever computer memory remained available to record detections. Signals from the 2 remaining Black Rockfish, however, indicate shorter periods of residency at the reef. Signals from one individual ceased abruptly after 6 weeks on the reef, perhaps due to fishing mortality or emigration. A second individual made excursions away from the reef and appears to have emigrated after 11 months of residency.

Receivers may have recorded signals from the transmitters originating up to several hundred metres away, and such distances would exceed the dimensions of the Point Atkinson reef. Therefore, we cannot exclude the possibility that Black Rockfish spent some of their time on soft substrates immediately adjacent to the reef rather than on the reef itself. However, extensive use of the adjacent soft-bottomed habitat seems unlikely because prior studies indicate that Black Rockfish (Johnson *et al.* 2003) and other *Sebastes* species (Love

et al. 2002; O'Farrell *et al.* 2009) select rocky habitats and use soft substrates infrequently. This does not preclude the possibility that Black Rockfish may emigrate by crossing such areas, and our study suggests that such behaviour does occur.

We suggest that most Black Rockfish remained within the small area of the Point Atkinson reef because the site provided structurally complex habitat and included a 45 m range of bottom depths within 30 horizontal metres. Our results, however, cannot distinguish the extent to which home site fidelity was determined by avoidance of poor quality habitats (surrounding mudflats) rather than attraction to the high-quality habitat of the reef. Regardless of the causal mechanisms, the observations reported here contrast with those of Black Rockfish studied in low-gradient coastlines, where average home ranges are 6 to 10 times greater than the isolated habitat patch used by Black Rockfish during this study (Parker *et al.* 2007; Green and Starr 2011). To improve the understanding of the relationship between movements and depth gradient, future work should be done with Black Rockfish at multiple locations where rocky habitats are structurally similar yet slope angles differ.

We acknowledge that the Black Rockfish in the study were translocated as young-of-the-year and reared to maturity in captivity, and this may have altered natural movement behaviour. Studies similar to this one, therefore, should be replicated with wild-caught adults with no period in captivity.

Acknowledgements

Animal rearing and handling protocols were approved by the Conservation and Research Committee of the Board of Governors of the Vancouver Aquarium Marine Science Centre. The study was funded by the Vancouver Aquarium and the Howe Sound Research and Conservation Group. Staff from Kintama Research surgically implanted the acoustic transmitters. We thank Claude B. Renaud and two anonymous reviewers for comments on an earlier draft.

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Notes

Historical Distribution Records and New Records Confirm and Extend the Distribution of the Silver Lamprey, *Ichthyomyzon unicuspis*, in the Hayes River, Hudson Bay Watershed, Manitoba

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Tyson, J. David, and Douglas A. Watkinson. 2013. Historical distribution records and new records confirm and extend the distribution of the Silver Lamprey, *Ichthyomyzon unicuspis*, in the Hayes River, Hudson Bay watershed, Manitoba. *Canadian Field-Naturalist* 127(3): 262–265.

We reviewed historical records and observations of the Silver Lamprey (*Ichthyomyzon unicuspis*) in the Hayes River in the Hudson Bay watershed. New records are presented from the Seeber River in the upper Hayes River system that extend the distribution of the Silver Lamprey in northern Manitoba. A new designatable unit for the Silver Lamprey, the Southern Hudson Bay–James Bay, is proposed.

Key Words: Silver Lamprey; *Ichthyomyzon unicuspis*; range; distribution; Hudson Bay; Manitoba

Silver Lamprey (*Ichthyomyzon unicuspis*) are found in lakes and rivers from Mississippi north in the Mississippi River system into Minnesota and west in the Missouri River system into Nebraska (Page and Burr 2011). They are found throughout the Great Lakes–St. Lawrence system as far east as the St. Lawrence River in Quebec and as far west as the Lake Superior watershed in Ontario (Page and Burr 2011). Limited numbers of Silver Lamprey have been collected in Manitoba.

The abundance of Silver Lamprey in Manitoba is poorly understood, but the distribution is likely more widespread than indicated by available records (Stewart and Watkinson 2007; Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2011*). Recent distribution accounts have included the Red, Assiniboine, Winnipeg, and Nelson rivers in the Hudson Bay watershed (Stewart and Watkinson 2007; COSEWIC 2011*) (Figure 1). The Rat River was formerly included in the Manitoba distribution (Stewart and Watkinson 2007; COSEWIC 2011*), but the specimen associated with the Rat River has been re-examined by M. Docker and identified as a Chestnut Lamprey (*Ichthyomyzon castaneus*).

The northernmost occurrence of the Silver Lamprey is near the mouth of the Nelson River at its confluence with Seal Creek (Figure 1) (Stewart and Watkinson 2007; COSEWIC 2011*). Hubbs and Trautman (1937) reported two specimens from the Hayes River. Both specimens are deposited in the Smithsonian National Museum of Natural History at the (USNM) (museum collection acronyms follow the Registry of Biological

Repositories (<http://www.biorepositories.org>)). However, recent accounts of the distribution of the Silver Lamprey have not included the Hayes River (Scott and Crossman 1979; Lee *et al.* 1980; Stewart and Watkinson 2007; COSEWIC 2011*; Page and Burr 2011; Renaud 2011).

Historical Records

The omission of the Hayes River records (USNM 32663 and USNM 63029) from recent distribution accounts may have been due to uncertainty in the collection localities of the specimens. USNM 63029 was collected in 1900 by E. A. Preble, and the locality was recorded in the National Museum of Natural History ledger as Hill River, York Factory. The locality was later clarified as Rock Portage on the Hill River branch of the Hayes River (Hubbs and Trautman 1937). Hill River and Rock Portage do not appear in the Canadian Geographical Names Data Base (Natural Resources Canada 2013). Hill River was the former name of the Hayes River between Knee Lake and the confluence with Fox River (Figure 1) (Franklin 1823; Preble 1902). In 1901, “Hayes” was applied to the entire length of the river and all former names were suspended (Ham 1980). Preble (1902) reported that Rock Portage was 15 miles (24.1 km) downstream of Brassy Hill; Rock Portage generally corresponds to the location identified on the Franklin (1823) map, when corrected for errors in longitude (Figure 1) (Houston 1994). Although Rock Portage was a navigational obstruction and the site of an important Hudson’s Bay Company transshipment depot

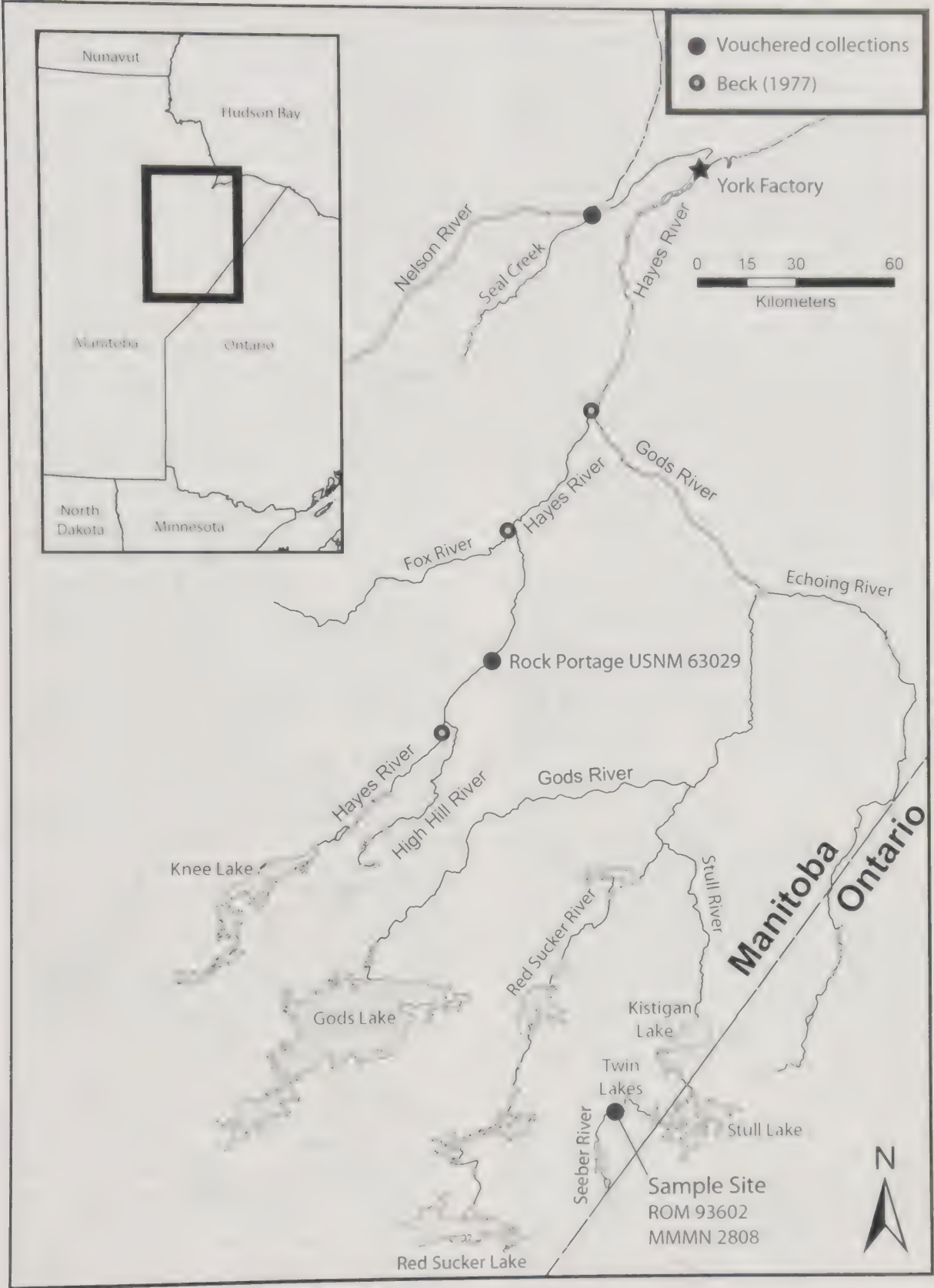


FIGURE 1. Locations of vouchered specimens and reported observations of Silver Lamprey, *Ichthyomyzon unicuspis*, in the Hayes River system, northeastern Manitoba.

(Rock Depot) (Voorhis 1930), there is no contemporary name for the feature (Natural Resources Canada 2013).

Specimen USNM 32663 was received by the National Museum of Natural History in 1883 from R. Bell, and the locality information was recorded as York Factory (Figure 1). No collection date was recorded. Although York Factory is situated on the west bank of the estuary of the Hayes River, this does not indicate conclusively that the specimen was collected within the Hayes River watershed. Bell (1879, 1880) made several trips throughout the Churchill, Nelson, and Hayes watersheds prior to the deposit date but made no mention of collecting the specimen. As with USNM 63029, it is likely that York Factory was used as a regional reference point for USNM 32663 rather than as a specific locality. When USNM 32663 and USNM 63029 were collected, York Factory was the most significant settlement in the sparsely populated District of Keewatin. The collection locality for USNM 32663 therefore remains uncertain.

Collections in 2011

USNM 63029 remained the only verifiable Silver Lamprey observation in the Hayes River system for more than a century until two adult Silver Lamprey were collected in the Seeber River, one on 6 September 2011 (Royal Ontario Museum 93602) and the second on 14 October 2011 (Manitoba Museum 2808) (Figure 1). The Seeber River is part of the Gods River system, and these specimens are the first documented and vouchered specimens from the upper Hayes River system.

The Seeber River specimens were attached to Northern Pike (*Esox lucius*), estimated to be 545 to 585 mm total length, collected by angling. The lampreys were tentatively identified in the field as Silver Lamprey, based on a single indented dorsal fin and unicuspid endolateral teeth on both sides of the oral disc. An identification key and description of lamprey from Renaud (2011) were used in the laboratory to confirm the identifications of the preserved specimens. The specimen collected in September 2011 was 112 mm total length, and the specimen collected in October 2011 was 125 mm total length. Specimen measurements were taken after preservation.

The Seeber River collection site (54.43942°N, 92.95308°W) is 2.8 km upstream of the Twin Lakes in a scour pool immediately downstream of a 40-m-wide boulder and bedrock chute. On 20 September 2011, the pool width was 90 m and maximum depth was 3.1 m over a substrate of cobble and boulders. The water velocity was approximately 0.9 m/second. Upstream of the collection site, the Seeber River contains a series of braided channel sections with runs, riffles, and rapids. Downstream of the collection site, the Seeber River channel expands into a series of two shallow flats ranging in width from 390 to 430 m. The flats

range from 0.5 to 1.5 m in depth with a substrate of silt, clay, organic matter, gravel, and boulders and contain dense beds of submerged and emergent macrophytes.

Discussion

The locality records likely do not represent a range extension for the Silver Lamprey; rather, the absence of vouchered records from these locations is a reflection of limited scientific sampling and cataloguing of fish specimens in this system. Beck (1977) recorded capturing Silver Lamprey at three locations within the Hayes River (at the confluence of the Hayes River and the Gods River, at the confluence of the Hayes River and the Fox River, and near the confluence of the Hayes River and the High Hill River) (Figure 1). Beck (1977) also reported observations of lamprey scars on fish as far upstream as Knee Lake. Voucher specimens were not retained by Beck (1977); therefore, the identifications cannot be independently confirmed. Beck (1977) speculated that Silver Lamprey were fairly common in the lower Hayes River.

Anglers have previously observed lampreys attached to host fish species at the Seeber River collection location, but these observations were not verified and documented until now. Prior to the collection of the voucher specimens, anglers in 2011 observed three lampreys attached to fishes, two Northern Pike and one Walleye (*Sander vitreus*), at the collection site. When shown the Silver Lamprey specimens referred to in this manuscript, aboriginal fishers from the community of Red Sucker Lake stated that lampreys are often observed throughout the Seeber River and Red Sucker River systems, with the exception of Red Sucker Lake.

The sample location for the Royal Ontario Museum (ROM) specimen (ROM 93602) and the Manitoba Museum (MMM) specimen (MMM 2808) is more than 430 river km upstream from USNM 63029 via the Gods, Red Sucker, and Stull rivers (Figure 1). The distribution of the Silver Lamprey likely extends throughout the Hayes River system in Manitoba and Ontario. Potential host species such as Lake Sturgeon (*Acipenser fulvescens*), Lake Whitefish (*Coregonus clupeaformis*), and Brook Trout (*Salvelinus fontinalis*) are known to move back and forth between the Hayes and Nelson river systems (Mandzy *et al.* 2007*; Laverigne *et al.* 2008*; Klassen 2012*). If movement between additional adjacent systems in the Hudson Bay watershed occurs, it is possible that Silver Lamprey are present in nearby systems.

The identification of the locality for USNM 63029 and the Seeber River records from 2011 have implications for Silver Lamprey conservation biology. The demarcation line between the Great Lakes–Upper St. Lawrence designatable unit (DU1) and the Saskatchewan–Nelson Rivers designatable unit (DU2) follows the divide between the Nelson and Hayes rivers (COSEWIC 2011*). This places the Hayes River system in DU1 (COSEWIC 2011*). The proximity of the

mouths of the Nelson River and the Hayes River, the observed movements of potential host species between the rivers, and the current understanding of postglacial dispersal routes suggest a Nelson River origin for the Silver Lamprey in the Hayes River (Stewart and Lindsey 1983; Mandrak and Crossman 1992). Until more information is available, we recommend that the Silver Lamprey in the Hayes River be placed in a separate designatable unit (Southern Hudson Bay–James Bay) in order to maintain consistency with the delineation of the national freshwater biogeographical zones (COSEWIC 2013*).

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First Records of the Northern Myotis (*Myotis septentrionalis*) from Labrador and Summer Distribution Records and Biology of Little Brown Bats (*Myotis lucifugus*) in Southern Labrador

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We conducted the first regional survey of bats in Labrador (Newfoundland and Labrador) to provide information on the distribution and biology of bats in this region. Our approach was to locate maternity roosts of *Myotis lucifugus* (Little Brown Bat) via word of mouth and then capture Little Brown Bats as they emerged from their day-roosts. We also surveyed for free-flying forest-dwelling bats using mist nets and a harp trap along forested trails and roads in southern Labrador. We captured 355 *M. lucifugus* at nine maternity roosts and one non-reproductive adult female *M. lucifugus* at a forested site. We captured two adult male *Myotis septentrionalis* (Northern Myotis) at two of the three forested sites (Gull Island and Grand Lake Road). These are the first confirmed records of this species from Labrador. Maternity roosts of *M. lucifugus* often had several hundred individuals. The proportion of female *M. lucifugus* captured at a roost that were either pregnant or lactating ranged from 35% to 96%; the estimated average date of parturition in 2012 was 10 July.

Key Words: Little Brown Bat; *Myotis lucifugus*; Northern Myotis; *Myotis septentrionalis*; parturition; Labrador; Newfoundland and Labrador

There is little information on the biology and distribution of bats in Labrador (Newfoundland and Labrador). Accounts of bats date back to the late 19th century, when naturalist excursions were made to the Labrador Peninsula. Low (1897) reported observing bats over the Hamilton River (now Churchill River) that he presumed were Little Brown Bats (*Myotis lucifugus*), and Bangs (1898) cited the observations of Low in his corrected list of the mammals of Labrador. Strong (1930) documented traditional ecological knowledge of bats as far north in Labrador as Davis Inlet from local Innu First Nations people. Eidmann (1935) reported records of *Myotis lucifugus* in Makkovik, and Nadin-Davis *et al.* (2008) reported the species from a rabies-positive bat submitted from Cartwright, Labrador.

Both Low (1897) and Bangs (1898) also reported a second species from the Labrador Peninsula by citing the observations of Stearns (1883) of a bat taken at Natashquan on the North Shore of Quebec. This bat is listed by Stearns (1883) as "*Vespertilio subulatus*, Little Brown Bat", although a later classification reports this species as *Myotis subulatus*, a synonym for the current species name *M. septentrionalis* (Northern Myotis). Although the true identification of the bat listed by Stearns (1883) cannot be verified, van Zyll de Jong (1985), presumably referring to the report in Stearns (1883), included *M. septentrionalis* from Natashquan, Quebec.

Regardless of the ambiguity of the report by Stearns, *Myotis septentrionalis* occurs in all adjacent jurisdictions (van Zyll de Jong 1985; Broders *et al.* 2003;

Henderson *et al.* 2009; Park and Broders 2012), and we expect that the distribution of *M. septentrionalis* might extend into Labrador. However, since no known systematic survey for bats has been conducted in Labrador, an understanding of their distribution and basic biology is lacking for the jurisdiction.

Given the paucity of information on bats in Labrador and the impending threats to their populations posed by white-nose syndrome (*Pseudogymnoascus destructans*, formerly *Geomyces destructans*) (Frick *et al.* 2010a), our goal was to collect baseline information on bats from the region. Specifically, our objectives were first to locate and survey maternity roosts of *Myotis lucifugus* to characterize distribution and reproductive biology (e.g., timing of parturition, reproductive rate) and second to determine whether the distribution of *M. septentrionalis* extends into Labrador.

Study Area and Methods

The study area was within the taiga shield and boreal shield ecozones (Ecological Stratification Working Group 1995). Generally, these areas were comprised of black spruce forest matrix with abundant bogs and stands of white birch, trembling aspen, balsam poplar, balsam fir, white spruce, eastern larch, and Jack pine (Roberts *et al.* 2006). Climatically, the average annual temperature is about 0°C and annual precipitation ranges from 900–1300 mm and snow persists for 6–8 months per year. Summers are short and cool with brief periods of higher temperatures (+25°C). Forest fires occur regularly (Wiken 1986; Roberts *et al.* 2006).

We collected reports from the public of nine *Myotis lucifugus* colonies in southern Labrador that were using buildings as maternity roosts (Figure 1). Following initial visual assessments of where the Little Brown Bats were potentially roosting in each building, we set various configurations of mist nets (Avinet Inc., Dryden, New York) and a harp trap (Austbat Research Equipment, Lower Plenty, Victoria, Australia) prior to sunset to capture Little Brown Bats as they emerged from the roost. Traps and nets were left open for between 30 and 180 minutes, with a goal of capturing 40–50 bats per roost. Trapping took place between 23 June and 28 July in 2011, 2012, and 2013.

To determine whether the distribution of *Myotis septentrionalis* extends into Labrador, we set two or three mist nets and a harp trap across forested roads and trails during one night of sampling at each of four candidate sites (Figure 1). We targeted mature forests as trapping areas, because this species typically roosts in decaying live trees or snags associated with such

stands (Jung *et al.* 1999; Broders and Forbes 2004; Garroway and Broders 2008; Park and Broders 2012).

Captured bats were held in individual bags until they were processed. Bats were identified to species, gender, and age class (juvenile or adult). Also, where possible, reproductive condition of females (pregnant, lactating, non-reproductive) was determined by gentle palpation of the abdomen and examination of the condition of nipples (Racey 1988). Damage to wing membranes was scored according to Reichard and Kunz (2009) as an indicator of the presence of white-nose syndrome. Any ectoparasites observed on the bats were noted and were sub-sampled opportunistically. All bats were released at the site of capture.

Colony size was crudely estimated by considering the number of bats captured, the number seen emerging from the roost that were not trapped, and a rough estimation of the number of bats left inside the roost, based on the noise generated by the bats within the roost once the traps were closed.

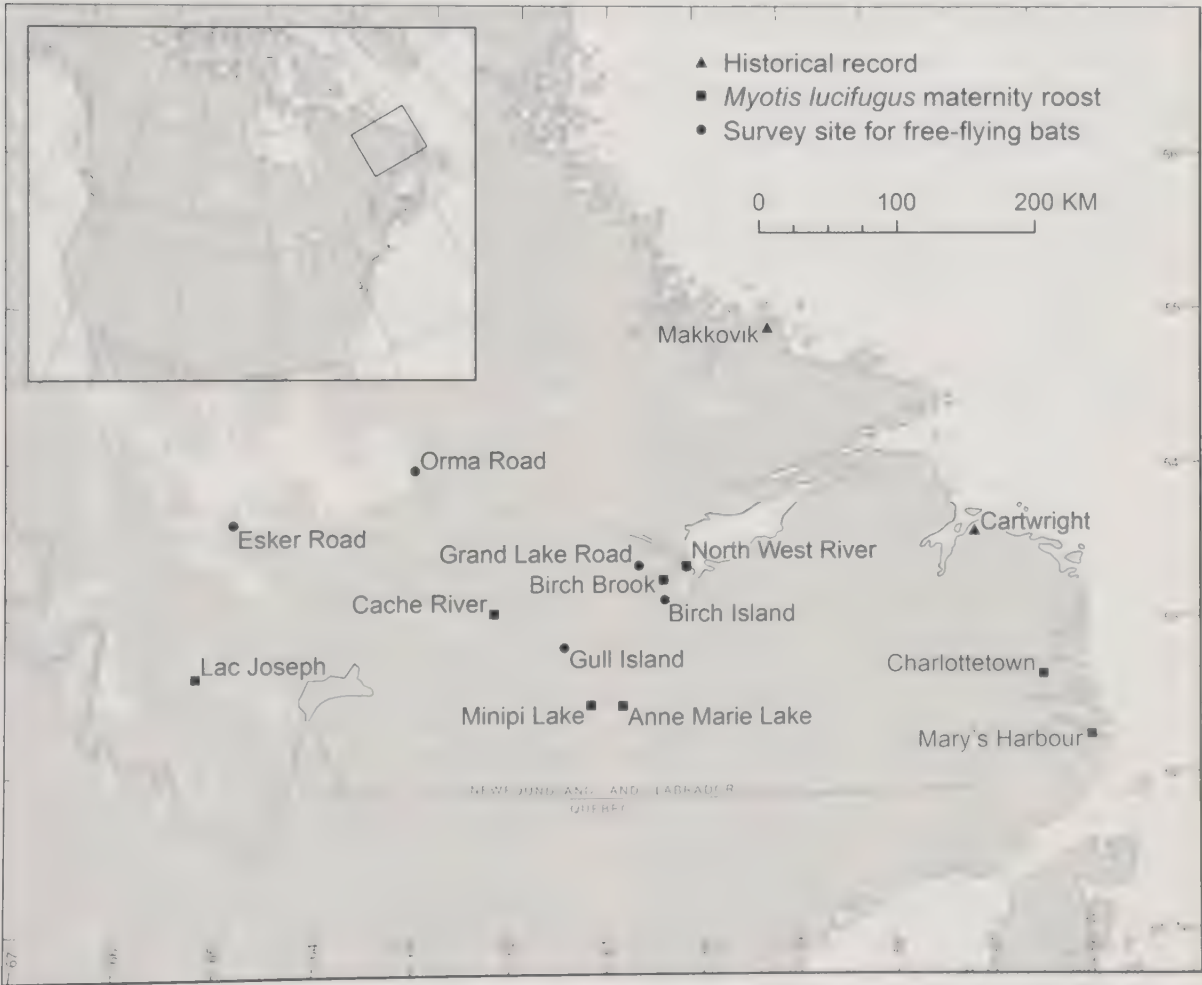


FIGURE 1. Locations of historical records and trapping survey sites for bats (*Myotis* spp.) in Labrador, 23 June to 28 July, 2011 to 2013. At *Myotis lucifugus* maternity roosts, we captured bats as they emerged at sunset. At free-flying capture sites, we used mist nets and a harp trap to capture commuting and foraging bats. At the Grand Lake Road site, we trapped at both the roost and the adjacent forest and have labelled it as a maternity roost.

This work was conducted under permits from the Newfoundland and Labrador Department of Environment and Conservation (Wildlife Division) and the Saint Mary's University Animal Care Committee. To minimize the risk of spread of pathogens (e.g., *Pseudogymnoascus destructans*), we ensured that none of the equipment and clothing used as part of these studies had been used outside Labrador.

Results

During the summers of 2011–2013, we live-trapped 355 *Myotis lucifugus* (329 adult females, 22 adult males, and 4 of undetermined gender) at nine maternity roosts in southern Labrador. Of these roosts, three were in abandoned cabins in remote areas (Lac Joseph, Cache River, and Charlottetown), two were in unoccupied buildings (in Birch Brook and Mary's Harbour), one was in an inhabited home (North West River), and the remaining three sites (Anne Marie Lake, Minipi Lake, and Grand Lake Road) were in seasonal buildings used during the summer.

Precise and accurate estimates of numbers of Little Brown Bats at each roost could not be made. However, on the nights of our surveys, it was clear that the roosts at each of Lac Joe, Cache River, Minipi Lake, and Anne Marie Lake consisted of >100 Little Brown Bats. The number of Little Brown Bats at each of the North West River, Birch Brook, Grand Lake Road, Mary's Harbour, and Charlottetown sites was probably fewer than 100.

We captured both lactating and pregnant Little Brown Bats on 9 and 12 July 2012 at Minipi Lake and at Cache River, respectively. We therefore estimate that the parturition date for Little Brown Bats in Labrador is approximately 10 July, but we are unable to make inference on variability in parturition date. When/where reproductive condition could be reliably determined, we estimated that the proportion of Little Brown Bats that were reproductive within a maternity roost was 35% (18/52) at Cache River in 2012, 36% (17/47) at Minipi Lake in 2012, 50% (13/26) at North West River in 2011, 73% (8/11) at Birch Brook in 2011, 89% (8/9) at Grand Lake Road in 2013, and 96% (47/49) at Lac Joe in 2011, assuming our sample of Little Brown Bats captured was not biased.

We did not systematically collect data on ectoparasites but, minimally, noted the presence of the Eastern Bat Bug (*Cimex adjunctus*), Bat Flea (*Myodopsylla insignis*), and mites (*Spinturnix* spp. and *Leptotrombidium myotis*). Anecdotally, it seemed that the prevalence and intensity of ectoparasites on *Myotis lucifugus* in maternity roosts in Labrador was greater than in other similar roosts in Nova Scotia and Newfoundland (HGB, unpublished data). Based only on examination of wing membranes of the bats (Reichard and Kunz 2009), there was no evidence that white-nose syndrome had reached Labrador at the time of our surveys.

During our free-flying capture surveys we captured an adult female *M. lucifugus* at Gull Island and seven

pregnant female *Myotis lucifugus* at Esker Road suggesting there was a maternity roost nearby. During these surveys we also captured one adult male *Myotis septentrionalis* at each of Gull Island and in the forest adjacent to the *M. lucifugus* maternity roost at Grand Lake Road. No bats were captured at either Birch Island or Orma Road. The captures of *M. septentrionalis* at Gull Island and Grand Lake Road are the first confirmed records of this species in Labrador. This extends the range northward from the observation by Stearns (1883) in Natashquan, Quebec, by >350 km.

Discussion

There are a number of maternity colonies of *Myotis lucifugus* (Little Brown Bats) in southern Labrador, and these bats use human-built dwellings as roosts. In this study, we have added 11 additional capture localities for the region, 9 of which are maternity roosts. Based on these results, we anticipate that there are a number of other maternity colonies in buildings in the region that were not sampled. It is not known if any natural structures (e.g., trees) were being used as maternity roosts. Little Brown Bats captured in the forest adjacent to Esker Road may have been using trees as roosts, since they were not observed coming from the cabin located at this site.

We confirmed the presence of *Myotis septentrionalis* in Labrador, and existing distribution maps should be updated (e.g., Naughton 2012). However, we still do not have a suitable characterization of the species' distribution or biology in Labrador. A systematic survey using similar live-trapping methods, mist nets, and harp traps of areas with mature forest and large trees is required to make inference of their distribution in the region.

The distribution of *Myotis septentrionalis* may be patchy. The presence of males at each of Gull Island and Grand Lake Road does not necessarily mean that reproductive females are also present, although they may be. Ideally, trapping surveys should be complemented by radio-telemetry surveys to locate maternity roosts and characterize colony dynamics. As further development affecting the extent and structure of forests occurs in the region, such work may be of conservation importance for the protection of this species, which is restricted to forested areas.

The average parturition date of 10 July for *Myotis lucifugus* in Labrador is among the latest recorded for the species, although individual parturition dates can vary by more than four weeks at any given location (Davis and Hitchcock 1965; Broders *et al.* 2006; Frick *et al.* 2010b). Despite this, the proportion of females that was pregnant in some roosts was quite high (up to 96%). It is possible that our sample was biased, as it consisted of the first animals captured. If there was a temporal bias in the emergence order of bats in relation to reproductive condition or if reproductive bats were

more or less capable of eluding capture, these data may not be representative of the colony.

Only $\approx 10\%$ of the forests in the region were classed as productive forests with commercial value (Wilton 1964), suggesting that trees of a diameter sufficiently large to support bat colonies are likely rare. Therefore, it seems possible that *Myotis lucifugus* relies heavily on buildings for maternity roosts, and we hypothesize that human dwellings facilitate the occurrence of the species in Labrador, which may be a limiting factor. Anecdotal evidence suggests that many local people have a low tolerance of bats inhabiting buildings. For this reason, an increase in education and outreach efforts regarding bat ecology and the value of roosts established in Labrador is recommended.

Identifying and monitoring any hibernacula within Labrador is of particular importance, given the recent emergence of white-nose syndrome, which can have severe population-level effects. At this point, there are no known overwintering sites for either *Myotis lucifugus* or *M. septentrionalis* in Labrador. Therefore, potential locations, such as the abandoned mine shafts in the Makkovik–Postville area, should be surveyed for overwintering bats.

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Impact of the Rust *Puccinia linkii* on Highbush Cranberry, *Viburnum edule*, near Smithers, British Columbia

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The berries of Highbush Cranberry (*Viburnum edule*) are an important food source for wildlife and for people in rural areas. In 2012 and 2013, many Highbush Cranberry plants in northwestern British Columbia were unusually severely infected by the rust *Puccinia linkii*, with telia covering up to half of each leaf. Given the ecological importance of the overwintering berries, I studied the impact of the infection on the production and quality of berries in mixed forests near Smithers, British Columbia. Sites where Highbush Cranberry bushes were infected with the rust had significantly more undeveloped berries. Plants from sites with higher levels of infection produced berries with significantly less sugar. Dead leaf tissue was also significantly more prevalent in infected plants. This study provides evidence that *Puccinia linkii* may stress plants, leading to reduced quality and quantity of berries, especially if the severity of the infection increases with the increasingly moist springs that are projected for the region.

Key Words: *Puccinia linkii*; *Viburnum edule*; Highbush Cranberry; rust; foliar pathogen; berry sweetness; effects of rust; British Columbia

Introduction

In the summer of 2012, Highbush Cranberry (*Viburnum edule*) (also known as Squashberry) bushes in sites near Smithers, British Columbia, had striking patterns of raised dark purple dots on their leaves formed by telia of the rust *Puccinia linkii* (Figure 1). This infection had not been noticeable in the area for at least a decade (personal observation, A. Woods, personal communication). The severity of the infection varied among sites and among plants: on some Highbush Cranberries, over 50% of each leaf was covered with telia; on others, there were only a few telia on a single leaf.

Highbush Cranberry bushes produce clusters of overwintering tart red berries that are high in vitamin C and antioxidants. They are an important food for animals (Pojar and MacKinnon 1994) (personal observation) and an important traditional food source for many First Nations people (MacKinnon *et al.* 2009; Dinstel and Johnson 2011). Many people living in rural areas make jelly from the berries.

Puccinia linkii is an autoecious rust that parasitizes *V. edule* in British Columbia (B. Callan, personal communication) (Kavak 2004). Herbarium records indicate the rust has a northern North American distribution (Farr and Rossman 2013). It has also been reported from Turkey (Kavak 2004). Specimens have been collected in most Canadian provinces on a small number of *Viburnum* spp. (Farr and Rossman 2013). Teliospores overwinter on the ground and are dispersed by the wind in spring. Very little is known about the impacts of *P. linkii* (Kavak 2004) (A. Woods, personal communication) (B. Callan, personal communication).

Puccinia linkii may have potential implications for food production, and foliage diseases may increase with climate change in sub-boreal forests (Woods *et al.* 2005) (A. Woods, personal communication). I hypothesized that highly infected *V. edule* plants would produce fewer berries, would lose berries before maturity, and would



FIGURE 1. Three leaves collected on 13 August 2012 from the same Highbush Cranberry (*Viburnum edule*) plant near Smithers, British Columbia (left to right, from the first, third, and sixth row down) showing pattern in distribution of telia of the rust *Puccinia linkii*. Photo: Karen Price.

produce less-sweet berries because *P. linkii* would reduce the amount of photosynthetic area on the leaves and absorb energy, leaving less for reproduction. I also hypothesized that rust would stress leaves and that highly infected leaves would die sooner.

Methods and Study Area

This study investigated *Puccinia linkii* in four moist, rich mixed coniferous–deciduous forests in the dry, cool Sub-Boreal Spruce biogeoclimatic subzone (SBSdk) (Banner *et al.* 1993) near Smithers, British Columbia. The four sites are identified as Home (54°39'01"N, 127°07'21"W), Cranberry (54°39'26"N, 127°07'55"W), River (54°39'45"N, 127°07'44"W), and Malkow (54°49'08"N, 127°06'21"W). Three sites (Home, Cranberry and River) were located on floodplains in the

SBSdk/08 biogeoclimatic site series and Malkow was on an SBSdk/06 hillside.

I marked 10 randomly selected *Viburnum edule* plants in each of Home, Cranberry and River sites, and 11 plants in Malkow (41 plants total) and used these focal plants to quantify the severity of the *P. linkii* infection, determine berry loss, determine the quality of the berries, test the sugar content of the berries, and quantify leaf mortality.

On 13 August 2012, I photographed the top leaf, third leaf, middle leaf, and bottom leaf (*in situ*, placed on a grid for scale) of each focal plant and used a graphic analysis program (ImageJ 1.44o, Rasband, 2013) to determine the size, density, and coverage of telia per leaf. I counted the total number of berries on focal plants twice, once on 13 August 2012 when they were starting to ripen and again on 25 September 2012 at the end of the season. Not all bushes produced berries.

A local jelly-maker collected baskets of berries from Highbush Cranberries from sites with high and low rust infection on 2 October 2012 using her standard picking methods, which include picking clusters of berries and removing unformed or diseased berries later. After the berries had been sorted, I counted the berries rejected by the jelly-maker in three high-infection and three low-infection samples and used a Mann-Whitney *U* test to determine the significance of the differences between the high- and the low-infection samples.

To determine the sugar content of fully formed mature berries and correlate it to infection severity, I collected three ripe berries from each of 68 plants (including from the focal plants and from additional randomly selected berry-producing plants) with different infection severities in three sites on 25 September 2012. Severity classes (low, moderate, and high) were based on the coverage and distribution of telia on each plant. If plants had more than one berry cluster, I collected berries from different clusters.

I pricked and squeezed each berry to extract a drop of juice, and I measured the sugar content (Brix) using a hand-held refractometer (Model RHW-25, Lee Valley Tools, Ottawa, Ontario). I determined the correlation between the mean sugar percentage per plant and the infection severity and I used a general linear model blocked by site for analysis.

To determine leaf mortality, I measured the percentage of each leaf that was brown weekly as leaves changed colour between 30 August and 25 September on the focal plants at three sites (Home, Cranberry and River). I determined the correlation between the colour change and infection severity (telia coverage determined above), and I used a general linear model blocked by site and plant for analysis.

To better understand historical patterns of infection, I searched the online herbaria databases of the Pacific Forestry Centre, the University of British Columbia, the U.S. Department of Agriculture, and Purdue Uni-

versity for records of *Puccinia linkii* from British Columbia, and I examined climate records (Environment Canada 2013) for the collection sites and dates.

A voucher specimen of *P. linkii* for this study has been deposited at the National Collection of Fungi on the Central Experimental Farm in Ottawa with the following number: DAOM 242721.

Results

Analysis showed that there was no correlation between the severity of the *Puccinia linkii* infection and the number of berries initially produced by the Highbush Cranberry plants.

It was not possible to detect any patterns in the number of berries lost during ripening, as many animals ate the berries from the plants selected (evidenced by piles of seeds and skins).

Berries collected to make jelly from plants in areas of high infection had 20 times more infected berries, with dark, hard patches, or undeveloped berries than berries collected from plants in areas of low infection. The mean percentage of rejected berries and standard error collected from plants in areas of high infection was $20.3\% \pm 1.9$ and in the low infection samples was $1.3\% \pm 0.2$. The differences were significant (Mann-Whitney *U* test: $P = 0.05$). Plants with higher levels of infection produced berries with less sugar (Figure 2) ($F_{1,63} = 19.4$, $P < 0.001$). These results were consistent among sites.

Dead tissue (brown colour) was higher on highly infected leaves ($F_{1,97} = 21.5$, $P < 0.001$), while less

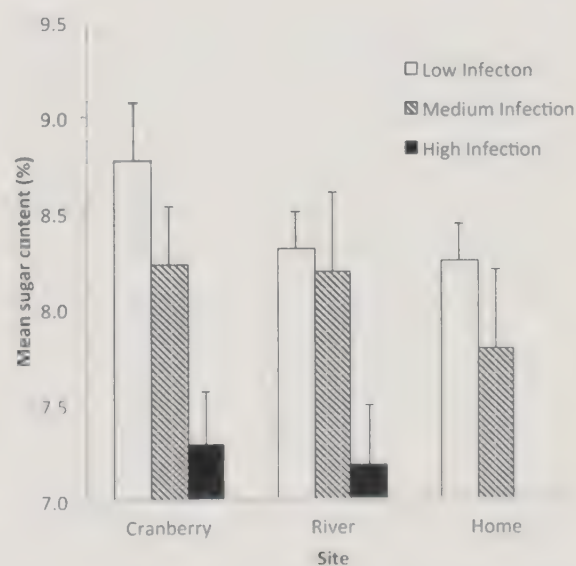


FIGURE 2. Mean percentage sugar in berries (error bars show standard error) collected on 25 September 2012 from 68 Highbush Cranberry (*Viburnum edule*) plants with different infection severities of the rust *Puccinia linkii* near Smithers, British Columbia (30 plants from the Cranberry site, 27 plants from the River site, and 11 plants from the Home site). Home site did not contain any plants with high infection severity.

infected leaves were mostly red (the expected colour in the fall).

Discussion

Viburnum edule plants that were highly infected produced more infected or unformed berries. The fully formed berries that these plants did produce had lower sugar content. This is probably because the rust reduces the plants' available energy by reducing photosynthetic area and by taking supplies from the plant (Inglese and Paul 2006) (rusts can cause plants to transport carbohydrates and minerals to infected sites (Littlefield 1981)). The fact that infected leaves turned browner sooner is consistent with stress to leaves.

Casual observations in the summer of 2013, the year following the study, indicate that the severity of the infection increased considerably in the area around Smithers and that *Puccinia linkii* has become more widespread. In addition, most bushes in 2013 had very few berries (possibly a result of reduced health during the previous season).

Other studies have documented the effects of native pathogens on hosts, with similar results. A rust (*Septoria albopunctata*) of the leaves of Premier rabbit-eye blueberry (a cultivar of *Vaccinium virgatum*) had a major effect: fewer flowers germinated, leaves fell off sooner, and the following year's yield was reduced (Ojiambo *et al.* 2007). *Puccinia lagenophorae* reduced the quantity of flowers of Groundsel (*Senecio vulgaris*) (also known as Common Ragwort) by 46%, and the plants showed signs of age sooner (Paul and Ayres 1987).

Impacts on foragers have also been documented, for example, autumnal moth larvae (*Epirrita autumnata*) eating infected mountain birch (*Betula pubescens*) leaves were smaller than those eating healthy leaves (Lappalainen *et al.* 1995).

I was unable to find studies documenting impacts of rust on sugar content, although the link between rust and reduced sugar content of fruits appears in brochures (e.g., Buchner 2012).

The effect of foliar pathogens varies from killing the plant to an almost commensalistic relationship with little observable impact on the host (Jarosz and Davelos 1995). Because pathogens usually reduce the ability of a plant to produce fruit, they have the least effect when their host can reproduce without producing seeds, such as by rhizomes (Jarosz and Davelos 1995). *Viburnum edule* can spread via rhizomes; over the long term, the effect of *Puccinia linkii* on the population is unknown, but it may have an effect on wildlife that depends on fruit.

Most leaf pathogens require specific weather conditions in order to germinate (Vallavieille-Pope *et al.* 1995). *Puccinia linkii* may thrive in wet springs, a condition that is predicted to increase in this area with climate change (Pacific Climate Impacts Consortium 2013). Woods *et al.* (2005) found an increase of the

Dothistroma needle blight with wetter summers likely related to climate change. Leaf rusts may be an indicator of increasingly wet conditions (Woods *et al.* 2005).

A search for collections of *P. linkii* in herbaria to look for patterns between wet springs and infection was inconclusive. There are at least eight collections of *P. linkii* from British Columbia, three of them from 1954. Climate records for this area (Environment Canada 2013) show that May 1954 was unusually wet; the first record of *P. linkii* in this area, in 1951, also coincided with a wet May. While there are not enough data to confirm a correlation with wet springs, these observations are consistent with this hypothesis.

This study provides evidence that *Puccinia linkii* may increasingly stress plants, leading to reduced quality and quantity of berries, especially if the severity of the infection increases with the moister springs that are projected for the region.

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Editorial

Young Scientists and their Mentors

We are pleased to publish the work of two young scientists in this issue of *The Canadian Field-Naturalist*. Adamo Young studied parasitoid wasps *Diadegma insulare* and *Microplitis plutellae* of the Diamondback Moth *Plutella xylostella* and Kiri Daust studied the impact of the Rust *Puccinia linkii* on Highbush Cranberry *Viburnum edule*. Both of these authors are Secondary School students, and both have won national awards for their work. As with any submission to *The Canadian Field-Naturalist*, these papers underwent the peer review process.

In corresponding with these two young scientists, it is immediately evident that they are self-motivated and enthusiastic about natural history and the pursuit of science. They both described years of recording observations and conducting investigations on natural history, and both have successfully competed in regional and national science fairs in Canada. Kiri described that participating in Science Fairs taught her to think analytically and to use science as a way of gaining knowledge about the world.

What is also evident is that both have benefitted from mentors. Dr. Peter Mason mentored Adamo in his lab at the Agriculture Canada Central Experimental

Farm. Peter introduced Adamo to biocontrol by introducing him to interactions between hosts and their parasitoids in the lab and the field. Peter taught Adamo the basics of science: how to identify a question, formulate a hypothesis, and conduct an experiment to verify or reject a hypothesis. Dr. Karen Price mentored Kiri in her observations in the field and throughout the analysis and write-up of her project.

Mentors play an instrumental role in the lives of young scientists. Good mentors are supportive of their students, but also willing to challenge ideas; they are approachable and patient; they are discerning in when to provide direction and when to allow the student to navigate his or her own way through a problem; they are observant and good listeners; and they exhibit a high level of enthusiasm for science. Good mentors help to make the process of doing science exciting. There is a long history of student mentoring among many of our natural history museums across Canada, and the Macoun Field Club, sponsored by the Ottawa Field Naturalists' Club, has been mentoring young naturalists for more than 50 years. This issue is dedicated to all of you who have helped to develop scientific investigating skills and to fan the flames of enthusiasm in young scientists.

Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

ZOOLOGY

The Eponym Dictionary of Amphibians

By Bo Beolens, Michael Watkins and Michael Grayson. 2013. Pelagic Publishing, P.O. Box 725, Exeter, UK, EX1 9QJ. 244 pages, 49.99 CAD, Cloth.

"An *eponym* is a person or thing, whether real or fictional, after which a particular place, tribe, era, discovery, or other item is named or thought to be named" <https://en.wikipedia.org/wiki/>.

Whereas the majority of scientific and English names of animals highlight a characteristic morphological feature or the country or continent where it occurs, some are named for a person or place. This compendium of people or of places featured in scientific and common names will appeal equally to both amphibian students interested in the historical origin of names and casual readers seeking entertainment. The authors are no strangers to such a hobby project but have varied backgrounds. The senior author, Richard Crombet-Beolens (Bo Beolens, known on-line as "Grumpy Old Birder and "Fatbirder") has spent much of his career in community work as the CEO of various charities, but has had articles published in a variety of birding magazines and co-authored three other eponym dictionaries, including *The Eponym Dictionary of Reptiles*, 2011, The Johns Hopkins University Press, Baltimore, Maryland. Michael Watkins, a retired London shipbroker, and Michael Grayson who was at the British library and is a Fellow of the Zoological Society of London are coauthors of both the earlier reptile and the present amphibian volumes.

The introduction gives the abbreviations used. Each entry is alphabetical by taxon named (generally species) as well as very brief (and partial) notes on the person honoured and the number of taxa in reptiles and birds which also honour the person. Species described from fossils are not included. A total of 2868 presently or recently living world amphibians are included, only 11 of which the authors' failed to trace their origin. Those traced are named for 1609 individual people, 228 that sound like, but are not, real people's names, plus 83 miscellaneous names from a variety of sources. Places or geographical features are sometimes honoured. Some that appear to have been named for a person are not. The salamander *Ambystoma jeffersonianum*, for example, is named not after a person but for Jefferson College, Pennsylvania. A few eponyms are based on fictional or mythological characters. For example,

Bilbo's Rain Frog, *Breviceps bagginsi*, is named for the senior hobbit in J. R. R. Tolkien's histories of Middle Earth.

Often, but not necessarily, a taxon is named for a person or persons who collected the specimen or for the place it was collected. Although describers cannot name a new taxon after themselves, a vernacular name can be for the describer, though more often it simply repeats that in that in the scientific name. A few scientific names acknowledged a sponsor who had financed the expedition on which the new a new taxon was found. In recent years a buyer can purchase a name for a new taxon. The German society BIOPAT is singled out for promoting donations from people, organizations and companies for taxonomic research in exchange being named and thus obtaining immortality for as long as formal nomenclature exists and the taxon continues to be regarded as valid. (Some museums, including a few in Canada, shamelessly even advertise this commercialization to supplement scarce research funds).

Two amphibian species first named from Canadian specimens are included in the dictionary but are generally no longer considered valid taxa: *Bufo* [now *Anaxyrus*] *copei* after E. D. Cope by the Americans Henry Crecy Yarrow and Henry Wetherbee Henshaw 1878 from James Bay, Ontario, and *Ambystoma tremblayi* from Cape Rouge, Quebec, by a Canadian, Wesley Comeau, 1943 for Jean-Louis Tremblay. Species that range into Canada that were first named from collections outside Canada include the Coastal Tailed Frog, *Ascaphus truei*, named for Frederick William True by Leonard Hess Stejneger, Fowler's Toad, *Anaxyrus fowleri*, for Samuel Page Fowler by M. H. Hinckley, Bullfrog *Lithobates* (formerly *Rana*) *catesbeianus*, named for naturalist Mark Catesby by George Shaw, and Blanchard's Cricket Frog, *Acris blanchardi*, (the latter now eradicated from Canada) named for herpetologist Frank N. Blanchard by Francis Harper. A western salamander, *Ensatina eschscholtzii*, was named for Johann Friedrich von Eschscholtz by John Edward Gray.

Regrettably, there is no index to describers, so to find Canadian herpetologists who have created eponyms for species beyond Canada the entire book has to be

searched entry by entry. Even then, if original descriptions are multi-authored by more than two, only the first author is given in the entry's reference. Only a few Canadian herpetologists have created eponyms for recent amphibian taxa beyond Canada. Examples in this book are J. P. Bogart (University of Guelph) *Tomopterna tandyi* Channing & Bogart, 1996, Tandy's Sand Frog

from South Africa, and Robert Murphy (Royal Ontario Museum) *Leptolalax sungi* Lathrop et al. [Lathrop, Murphy, Orlov & Cuc] 1998, Sung Toad from Vietnam.

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Field Guide to Jewel Beetles (Coleoptera: Buprestidae) of Northeastern North America

By S. M. Paiero, M. Jackson, A. Jewiss-Gaines, T. Kimoto, B. D. Gill, B. D. and S. A. Marshall. 2012. Canadian Food Inspection Agency. 411 pages.

Recently published by the Canadian Food Inspection Agency, in collaboration with the University of Guelph, Ontario Ministry of Natural Resources and the Invasive Species Centre, this field guide is *not* found in a bookstore near you. Remarkably, *Field Guide to Jewel Beetles of Northeastern North America* is available free of charge from the CFIA, and is as attractive as the group it covers.

Also known as metallic or short-horned wood-boring beetles, jewel beetles have long attracted interest for their iridescent beauty and diversity. They belong to a large, economically important family, with perhaps 15,000 species worldwide. The most notorious of the 700 or so species in North America is the Emerald Ash Borer. This field guide is particularly timely given the massive economic and ecological impacts this invasive species is having in eastern forests since it first arrived in the early 1990s.

Professional entomologists will be familiar with Agriculture Canada's *The Metallic Wood-boring Beetles of Canada and Alaska* (Bright 1987). Paiero et al.'s new field guide includes an updated taxonomy and recent arrivals, and will greatly facilitate identification of the 164 jewel beetle species known or expected to occur in northeastern North America. To place as many copies as possible in the hands of entomologists, foresters, arborists, technicians, woodlot owners, and naturalists, it is available in both English and French and at no cost.

This field guide has a brief introductory section along with information on jewel beetle sampling, curation of specimens, and their submission for species confirmation. It even includes a section (with photos) on how to dissect male jewel beetle genitalia. While it might strike some as odd (or worse), the reproductive structures of male jewel beetles are often diagnostic.

The dichotomous keys and species treatments that form the bulk of the book set this guide apart. It includes two identification keys for the 23 genera in northeastern North America. One is a "technical key" modified from existing scientific literature that uses the most reliable characters, even if they require a microscope. The other "field key" uses characters that are more easily observed in the field with a hand lens or digital camera, but may lead to several end points due

to character variability. Photographs accompany each couplet in the keys, enhancing ease of use. Each species is vividly illustrated with high-resolution colour photos of the dorsal and ventral views (including additional colour morphs where available), as well as the head and male genitalia. Lateral photos and additional identification aids (icons) are also included for the 60 odd species of *Agrilus*, the most diverse genus in the northeast.

Species accounts are well laid out, organized alphabetically by subfamily and genus, and include colour-coded headers for easy navigation. Full scientific names including authorities and taxonomic synonyms are given, which can help link species concepts with published technical works. Diagnostic characters, similar species, and known larval host plants are also provided in the species accounts, as well as common names and general ecological notes where available. It is also noted whether or not each species is a known prey of *Cerceris fumipennis*, a buprestid-hunting wasp whose nests can be raided for jewel beetle specimens. Particularly useful are nested silhouettes showing minimum and maximum recorded size for each species. The range maps show both the jurisdictions (state, province) in which a species has been recorded, as well as the geographic range of its known larval host plants. It's a novel and useful approach; although a lighter shade of green would have made the maps a bit clearer.

I am loathe to criticise such an excellent publication, all the more so when it is free. I do wonder however, if there was perhaps a missed opportunity to make the guide even more accessible to its intended audience. It is unfortunate that ES-recognized common names were available for only 19 of the species covered in the field guide, and those few are not listed in the index. Many recent field guides for other North American groups (e.g., as tiger beetles, ants, and odonates) have often included species or genus-level information on habitat, behaviour, and/or phenology. Although this guide was primarily intended for identification of jewel beetles, more natural history information (perhaps as an expanded *Comments* section) could have broadened its appeal. Perhaps future editions may be able to incorporate additional ecological information, particularly for lesser known species that are not economically important.

These minor criticisms aside, I think this book will stimulate an inordinate fondness for jewel beetles. As a group, they have many of the attributes that appeal to amateur naturalists: they are attractive, not too challenging to sample and diverse enough to be interesting (but not overwhelmingly speciose). This superb field guide will enable citizen scientists to contribute to a better

understanding of jewel beetle distribution, abundance, and ecology. To obtain a copy, please call the CFIA at 1-800-442-2342.

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The Boreal Owl: Ecology, Behaviour and Conservation of a Forest-dwelling Predator

By Erkki Korpimäki and Harri Hakkarainen. 2012. Cambridge University Press, 100 Brook Hill Road, West Nyack, NY, U.S.A. 10994-2133. xiv + 359 pages, 96.95 CAD, Cloth.

The pre-eminence of Scandinavians and Finns in studying northern forest owls became evident in 1987 at the Symposium on the Biology and Conservation of Northern Forest Owls in Winnipeg. The strength of the present fact-filled book by Korpimäki and Hakkarainen 25 years later has set a new and even higher standard. The extensive bibliography includes 67 major publications by Korpimäki and 20 by Hakkarainen.

I was amazed at the numbers of Boreal Owls and nests monitored each year in the main study area near Kauhava in western Finland. At the latitude of 63° North, these owls depend on Field Voles *Microtus agrestis*, for food, an extreme example of “boom and bust” food availability. This vole follows a three-year cycle in numbers over large areas, at times a 1000-fold difference between highs and lows, whereas in southern Europe their fluctuations are only 10-fold. Other Boreal Owl prey items are Bank Voles, shrews and birds. Since 1982, 1224 female, 994 male, and 4158 fledgling Boreal Owls have been trapped and banded at 1135 occupied nests.

Nearly one-third (32%) of Boreal Owl nests were in natural cavities made by the Black Woodpecker; the remaining 68% were in 450 to 500 nest boxes monitored annually. Natural nests and man-made boxes were visited over 41,000 times, requiring 10,000 hours of field work. Over 20% of nest boxes 1 to 4 years old were occupied, compared to less than 10% for older boxes in place for 11 to 18 years. No less than 27,759 prey items were analyzed, including 12,554 from nests, 1560 in prey detritus layers in nests, and 819 in 117 roosting holes and nest-boxes in winter. The prey items were positively correlated with the number of owl fledglings.

In the 1950s and 1960s, the Boreal Owl was the most common bird of prey in the coniferous forests of Finland and Sweden. Sadly, with continuing destruction of old-growth forests and in spite of provision of thousands of nest boxes, its population has since decreased steadily by 2.1 to 2.3% per year. About 15% of the nest boxes placed in spruce forests but only 8% in pine forests were occupied by Boreal Owls. Radio-tracking of 24 Boreal Owls confirmed their preference for spruce-dominated forests and their avoidance of large open areas in spite of voles being more numerous there.

Boreal Owl home range size varied from 73 to 499 ha and the nocturnal hunting range size was 94 to 226 ha.

At Kauhava, males were site-tenacious after their first breeding attempt, whereas adult females and juveniles were nomadic, traveling long distances when voles were scarce. There was a striking cyclical 21-fold difference in the number of fledglings that survived to the end of the season in the study area, varying from 3 (twice) in low vole years to 81 and 87 in high vole years. Vole populations meanwhile varied 45-fold. In poor vole years, light and long-tailed males were more economical fliers and efficient hunters than heavy males.

Most pairs are monogamous, but most pair bonds last for only one breeding season. Female owls, strictly fed by the males, stay in or near the nest-box and put on weight for 2 or 3 weeks prior to egg-laying. At Kauhava 24% of males were unmated bachelors that nevertheless possessed a home range and a nest-box, even in good vole years; 66% of males were monogamous and 10% polygynous in good vole years. One extremely productive male paired with at least nine females that laid 51 eggs, of which 46 hatched, 26 fledged but only 3 lived to breed. However, two other males raised 10 and 20 fledglings during their lifetime.

The start of egg-laying was earliest (mean laying date 13 March) in the decline phase of the vole cycle, and the latest (mean date of 2 May) in a low vole year. The yearly mean clutch size varied from 3.6 to 6.7, the latter in a good vole year. An average of 13.3% of eggs failed to hatch. The mean number of hatchlings varied from 2.5 to 5.8, with a mean of 4.95, but only 2.95 fledged, this final decrease largely due to starvation in low vole years.

Lifetime reproductive success (LRS) is the most important determinant of an individual's fitness, but can be studied only in males that remain in the study area. Females, on the other hand, show long breeding dispersal distances, often beyond study areas. Of 141 males whose lifetime production of young was recorded, mean lifespan was 3.5 years, with a maximum of 11 years in Finland and 13 years, twice, in Germany. At Kauhava, 25% of males first bred at 1 year, 51% at 2 years and 24% at or beyond 3 years. Most males bred only once, hence 50% of the fledglings produced were

fathered by 31 of the 141 males. In low vole years, only about one-tenth of males managed to breed and only 25% survived the winter, versus 75% in good vole winters. LRS was highest in old-growth forest, where there is better refuge against larger owl predators and greater availability of voles.

When a male had two females (polygyny), the first female raised 83% of her eggs to the fledgling stage, whereas the second female, on average 2827 m distant, laid eggs later, had less provisioning from the male, and raised only 49% of her eggs to fledglings. Polygynous males added to their reproductive success; when mated to three females they contributed to 9 fledglings, with two females, 6 fledglings, and when monogamous that year, 4 fledglings.

The authors test a number of hypotheses to good effect, adding to the scientific value and the reader's interest. For example, dispersal of Boreal Owls could be consistent with resource competition, predation risk, reproductive success, or food depletion, with evidence predominantly favouring the latter.

Finnish ringing data showed 83 males and 211 females were recaptured elsewhere after being ringed as

nestlings. The median and maximum distances moved by males was 14 km and 409 km; for females, 62 km and 1099 km. The few published papers about breeding Boreal Owls in Alaska and the Rocky Mountains from Idaho and Montana south to Colorado are summarized.

I have only minor criticisms. I would have preferred totals at the bottom of appropriate columns and a map with lines to show the precise movement of each long-distance female dispersal. Precise definitions of "cyclicality index" and of H , used in the Kruskal-Wallis test, would have helped me.

This sumptuous book, written by the world's foremost Boreal Owl experts and chock full of interesting information barely skimmed in this review, is literally "worth its weight in gold." It should stimulate a few Canadians to undertake detailed breeding studies wherever populations are accessible, perhaps in Quebec. It is highly recommended for every University library and for every keen owl student throughout the world.

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Primates of the World – An Illustrated Guide

By Jean-Jacques Petter and François Desbordes (Translated by Robert Martin). 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 186 pages, 29.95 USD, Cloth.

Princeton has taken a French book and expanded the audience by publishing it in English. Normally such translations suffer from odd phrases that identify the translator as a non-naturalist. Robert Martin has created and excellent translation that reads smoothly and is easy to comprehend. There are some idiomatic peculiarities, but I did not find these interfered with the sense or my enjoyment.

The author covers the evolution of the first mammals and the arrival of the earliest primates. This starts with lemurs of Madagascar and their likely path to diversity. Lemurs are the author's speciality so this group tends to bias the discussions. Following the primate evolutionary path is a little eerie as so much seems to relate to us humans. The author summarises the biology of primates as a whole, giving note to their feeding and breeding habits. He examines the role of predators (and the occasional predatory actions of primates). He particularly relates the role of forests in primate development. Although short the section on communication and intelligence are quite revealing.

The author discusses classification of primates and start with a family tree diagram. They then tabulate by Family the species of primate. I noticed that the Western Hoolock Gibbon (*Hoolock hoolock*) is placed in it's currently accepted genus of *Hoolock*. This change was made when the species was split into Eastern Hoolock (*Hoolock leuconedys*) and Western based on differences in facial and genital hair. Yet the Eastern

Hoolock is not mentioned nor is the genus *Hoolock* in the index. However in this classification section it notes there are two species, but lists just one. So I looked at the other genera and found there were other species missing. Among the macaques I realised Northern Pig-tailed Macaque, *Macaca leonina*, Siberut macaque, *M. siberu*, Gorontalo macaque, *M. nigrescens* and Arunachal macaque, *M. munzala* had been left out. Only two of the eight species of Woolly Lemurs are included. In fact the book covers just over 50 per cent of the non-human primates.

The discussion and classification sections are illustrated with coloured sketches. These are like the artist's field notes and are a bit more rudimentary than I like. The illustrations of the individual species, however, are superb. They are accurate in a photographic sense, but are far more than a photo. They give the "feel" of the animal; its posture, furriness, facial expression etc. These are about the best mammal paintings I have seen. Congratulations to France Desbordes.

For each genus there is a basic discussion of characteristics of the group opposite each plate. This section is arranged by geographic region; Madagascar, South America, Asia and Africa. The range maps are easy to interpret and will be most useful. The book ends with Gorilla, Chimpanzee and Bonobo – our closest relatives.

This book is a combination of values. The first part is a readable text that can be enjoyed at leisure. The

last half is a reference volume for the species most travellers are likely to encounter. The whole book gives a fascinating insight into this intriguing and intelligent group of mammals. It is good value for the price.

Pterosaurs

By Mark P. Witton. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 291 pages. 35.00 USD, Cloth.

Not since Bakker's *The Dinosaur Heresies*, have I been so enthralled with reading a book on prehistoric life. This is an amazing book. The cover art sets the scene (go ahead, judge the book by its cover), and before reading a single word inside, I flipped through the book's many, many illustrations. There are line drawings (some coloured), photographs of fossils, maps and... paintings. The paintings...absolutely stunning. Although the text is quite technical, one could still give this book to a seven year old and she would be enthralled flipping the pages, just admiring the artwork. In fact, I loaned my copy to a colleague with six and eight year old girls and they were enthralled, and inundated their mother with many, many questions. Witton has used some artistic license in colouring the pterosaurs, and also in fleshing them out, but the reader (whether seven or 97 years old) is presented with animals hatching, foraging, feeding, launching, flying, dying and walking. Walking...wow, what we've learned in the last few decades! But I digress...there are dozens of paintings, making me wonder if the author/artist was actually a researcher in the field (yup, I checked)...where did he find the time?

Although the text is mostly technical, directed at an informed audience, it is written with a humorous slant. Everyone will get something out of reading this book. Witton makes a point of referring to a large body of the pterosaur literature, starting with Collini's description of the first-discovered fossil (from the same deposits which gave us *Archaeopteryx*) to the most recent literature which could be accessed, some of it even in prep. The fairness with which Witton treats the literature representing opposing and unconventional viewpoints is quite professional. In such a book, other authors may not have even bothered to include different viewpoints. Additionally, the dogma is challenged and either debunked or corroborated.

The book is organized like *Squirrels of the World*, *Birds of Delaware* and many others dealing with a clade of organisms...several introductory chapters are followed by chapters on the more restricted clades. And this formula works. In this case, the introductory chapters deal with topics like anatomy, flight, nonvolant locomotion and more. Sixteen further chapters deal with families (or groups of certainly close, but uncer-

tain affiliations) of these flying reptiles. Each chapter is divided into four major sections. The introduction provides a brief description of the group. There is a summary of fossil locations with a map showing these. In one of very few critiques I have of the book, the maps seem cluttered with the species-labelled leader lines crossing continents (numbered dots with tabulation in the caption would have worked much better). The taxonomy of the group is discussed, with reference to several, often many individual specimens. The anatomy of each clade is described as the second part of the family accounts.

Understandably, this section is dominated by a discussion of the skeleton, but mention of soft tissues is made, when available. A line drawing of at least one reconstructed skeleton is presented in launch position, accompanied by a fleshed out specimen in the same posture.

The final two sections of the family accounts are based on the previously described anatomy. Locomotion for both flight and terrestrial locomotion are covered, including climbing for those thought to be arboreally inclined. Witton attempts to paint (textually and literally) each animal in its world, whether that be as a wading filter feeder, a courting wanna-be dad or a flock attempting to migrate to an earlier era to avoid extinction (that being an example of the author's humour, not the reviewer's).

Despite the marvels which make up this book, there are a few, largely minor changes I would have made. The endpapers are blank...the audience for this book includes folks like me whose recitability of the geologic scale is rusty, and would have benefited from one there. Two time scales are within the body of the book, but the endpaper is really where one ought to be. Another endpaper could have had a labelled line drawing of a skeleton with superimposed wing membranes. The anatomies of these animals is critical to the discussions throughout, and those not anatomically-inclined may have benefited from an easily accessible, labelled skeleton.

All in all those, a fantastic book!

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The Secret World of Red Wolves: The Fight to Save North America's Other Wolf

By T. DeLene Beeland. 2013. University of North Carolina Press, Chapel Hill, NC, USA, 27514-3808. 272 pages, 28.00 USD, Cloth.

As I sit on the shoreline of Washburn's Island just off the southern coast of Cape Cod, Massachusetts, during a weeklong camping trip in the late summer heat, I take a pause from reading *The Secret World of Red Wolves*. I daydream of wolves that may have formerly roamed this small island and the tracks and howls of the coyote-wolf hybrids that currently call this place home. These animals are typically called eastern coyotes but I prefer the term coywolf to better describe the hybrids that live throughout the northeastern United States. Personally, I am amazed by how much the red wolf looks like the coywolves that I have studied in Massachusetts for the past 15 years, which shouldn't be too surprising since they have similar DNA. The coywolf arose as part of a hybridization episode that took place about 100 years ago between the medium-sized eastern wolf, which may be the same species as the red wolf but lives about 1000 miles away, and western coyotes just south of Algonquin Provincial Park, Ontario. I am amazed at how adaptable and flexible the genus *Canis* is as this hybrid canid has successfully colonized the entire northeast U.S., including here on Cape Cod, whereas neither of their parent species has been able to get a toehold in the same area.

The Secret World of Red Wolves is a very important addition to any wolf aficionado's library and is easily the definitive and most complete book written on the subject. It does an admiral job of summarizing the red wolf from its origins to current research, explores efforts to re-establish this carnivore, and even considers future threats to the species. The book is divided into three major sections and at the end of each chapter, Beeland provides great transitions which make for an engaging, turn-paging read! This book will appeal to wildlife professionals, field biologists, conservation students, animal lovers, and anyone interested in North America's fauna, including layman readers, as it is very easy to read.

The first section, *The Red Wolf Today*, nicely describes the efforts to re-establish a population of wild wolves in northeastern North Carolina. Written in first-person narrative, it brings a boots-to-the-ground style to the book as the reader learns first-hand of current restoration efforts in the Red Wolf Recovery Area (RWRA) where a wild population of about 100 red wolves currently lives. We meet the red wolf biologists and some of the red wolves themselves, and learn how hybridization with coyotes and human-caused mortality severely threaten this endangered species. We find out about the amazingly intensive hands-on management where each wolf is certified as a wolf or potential coyote \times red wolf cross, and how biologist manage to minimize the influence of coyotes which have colonized the region and readily hybridize with the closely-related

red wolf. Descriptions of sterilizing and releasing coyotes, and tracking them and their red wolf "friends", make for engaging reading and remind me of some of my experiences radio-tracking coywolves in Massachusetts. Field biologists will readily relate to the scenes where Beeland describes the day-to-day work of tracking, radio-collaring, and monitoring wild canids, while layman readers will gain greater insight into wildlife research and red wolf behaviour. Finally, a black and white photo gallery nicely separates sections one and two (and also parts 2 and 3) and shows the reader what red wolves look like.

The second section, *The Red Wolf Yesterday*, succinctly explores the background of the red wolf and how it was saved from extinction. We learn about some of the early biologists and trappers that literally captured each known remaining red wolf from the wild, and brought them into captivity to be bred. While many canids were captured, only 14 pure red wolves with no known coyote ancestry eventually contributed to the breeding program. The offspring of these wolves eventually formed the seed to re-establish the wolves eloquently described in part 1. In part 2, we also learn of the scientific debate among biologists of just what the red wolf is. Beeland outlines the two top competing models of red wolf origins, the first being that they arose as hybrids between coyotes and gray wolves, and the second being that they represent an offshoot from a shared lineage with coyotes. Like Beeland, I subscribe to the shared-ancestry theory where red wolves and eastern wolves (currently living in southeastern Ontario, Canada) are the same or very closely related species, and in which both are very closely related to coyotes. It makes the most sense as they are the only wolves that mate with coyotes; even small gray wolves do not. In fact, red and eastern wolves could be thought of as coyote-like wolves that evolved in eastern North America, while coyotes developed in the central part of the continent, and gray wolves crossed the Bering Land Bridge to populate most of North America outside of the East. The relatively recent degradation of habitat and decimation of wolves has allowed coyotes to colonize the East and interact (i.e., hybridize) with their closely related brethren.

The last section, *The Red Wolf Tomorrow*, describes current threats to the long-term survival of red wolves which includes pressing issues surrounding hybridization and human-caused mortality, and sea-level rise due to climate change. It is depressing to me how most state wildlife departments treat coyotes (and predators in general) so poorly, and the state of North Carolina pathetically allows these animals to be slaughtered year-round and now even at night. A lawsuit temporarily prevented this from happening within the RWRA.

but there is ongoing litigation to prevent an open day-light and night season on coyotes within the RWRA. While there are ethical and biological problems with allowing this to occur on a common yet ecologically important species, especially without addressing any specific management outcome, Beeland also exposes the problems of how the visual similarity between some red wolves and coyotes results in the open season on coyotes leading to red wolves also being shot. She documents the actions of people who reportedly said "I thought I killed a coyote" when it was actually a red wolf they shot, and how they only get a slap on the wrist and are not prosecuted for violating the law. This is criminal in my opinion, yet also occurs in the northeast U.S. when eastern wolves are killed by "coyote" (really coywolf) hunters in New England and New York. Part 3 concludes with a chapter on climate change, which reveals a sobering reality of the pervasive effects that humans have had on the world. While the far eastern coastal location of the RWRA was partly selected for in 1987 because no coyotes lived there at the time, it is now battling ever rising seas. This was the grimmest and most sobering chapter in the book, in my opinion, as the question is not will red wolves lose habitat due to rising sea levels in the future, but how much will they lose?

I believe that the success of the recovery program will centre on fully protecting both red wolves and coyotes within the RWRA in order to reduce red wolf deaths and hybridization episodes, which has been found to be closely linked to human-caused red wolf mortality. Similarly, there has been tremendous success of establishing a buffer (i.e., no hunting) protection zone of all canids around Algonquin Park which

has reduced eastern wolf mortality and hybridization with coyotes in and around the park. If there is one thing I believe the book missed, it would be a stronger call to suggest this protection requirement and to urge the state of North Carolina to not willingly neglect its responsibilities for protecting this unique canid. I believe that federal law should force the state to protect all *Canis* in the recovery area and beyond through a similarity of appearance clause which quite simply means that because coyotes look so similar to red wolves both need to be protected to prevent red wolves from getting killed. We owe them at least that much.

Hopefully with a reduction of human-caused mortality in their recovery area, red wolves can hold on as a species in northeastern North Carolina similar to eastern wolves in Algonquin Park. And outside of that zone red wolves and coyotes would be left to their own devices to sort out what kind of canid is best able to thrive in a human-dominated landscape similar to how the coywolf that I study in Massachusetts formed in southern Ontario about a century ago. How hard is it for us humans to step back and watch this evolutionary process unfold without unneeded management, or killing, of these awesome and important animals?

Overall, readers will find this treatise to be an easy-to-read page turner that is a timely and a welcomed book on 'North America's other wolf'. The story of the red wolf was waiting to be told, as Beeland accurately puts it on page 229, and it is a fine story at that. Readers will have a much better appreciation for the red wolf and hopefully new conservationists will champion the recovery of this species; they certainly need it.

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OTHER

An Introduction to Population Genetics: Theory and Application

By Erasmus Nielsen and Montgomery Slatkin. 2013. Sinauer Associates, Inc., Publishers, Sunderland, MA, USA. 01375-0407. 298 pages, 62.95 USD, Cloth.

This textbook approaches population genetics from the perspective of coalescence theory which focuses on coalescence events where species lineages have merged. It contrasts with the more common classical approach by working backward from the present individual sample rather than forward from an earlier ancestor. In this text, both approaches are combined to examine the application of coalescence theory to human populations and populations of other organisms.

The authors have written this text for advanced undergraduate and graduate students with basic algebra and genetics training. The text introduces concepts from probability and statistics. In my opinion, the authors are probably hitting a much higher preparation level than this and students should have some probability and sta-

tistics background to fully understand the concepts and the material may be challenging to students without this background. Although the math presented in this text is more complex than basic algebra, it can likely be understood with that background although I think intermediate or advanced level algebra would give students a leg up. An introduction to Bayesian theory would also be worthwhile if the instructor was not grounded in this area.

Overall, the text proceeds through reviewing allele and gene frequencies, Hardy-Weinberg equilibrium, genetic drift, and mutation. It devotes limited space to bottlenecks which is a significant concept in population genetics and of great relevance to conservation. The remainder of the book addresses coalescence theo-

ry and how this theory is applied to analysing genetic data from populations. Appendices provide a quick introduction to probability theory, the exponential distribution, maximum likelihood and Bayesian statistical concepts, and a Chi-square table.

For classroom use, the authors provide chapter exercises and answers are provided for the odd-numbered ones. The layout and graphics are high quality and the text is error free.

My general conclusion of this text is that it is likely of interest only to instructors teaching a population genetics course that is advanced and focussed entirely

on coalescence theory. Its reference value is the same; limited to coalescence rather than classical population genetics. The by-word here is advanced as I believe the student will need to be somewhat advanced as well in his/her biological and quantitative background. I recommend this text only in that context and would encourage use of other available population genetics texts instead.

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The Reindeer Botanist: Alf Erling Porsild, 1901–1977

By Wendy Dathan. 2012. University of Calgary Press, 2500 University Drive N.W., Calgary, AB, Canada. T2N 1N4. 726 pages. 44.95 CAD, Paper.

Erling Porsild is a legendary figure in Canadian botany. His personal accomplishments as an explorer, taxonomist and biogeographer have rightly earned him a place of honour in Canadian science. More than that, his career crossed an important transition in floristic research. When he arrived in this country, vast swaths of the boreal and arctic regions of Canada had never been visited by biologists. By the end of his career, he had personally documented the flora of large parts of the Yukon, Northwest Territories, and the Hudson Bay Lowlands, and the number of places in Canada's far north that remained unknown to science was shrinking fast.

Wendy Dathan has done an admirable job in compiling Porsild's biography. This is a fantastically detailed treatment. She starts at the beginning, which for Porsild was Greenland. He truly was born into the life of an Arctic botanist, moving to the island of Disko off the west coast of Greenland when he was five. His father, an accomplished botanist himself, had the job of establishing a permanent research station in the Danish colony.

The elder Porsild had some sway with Canadian botanists, and later helped land Erling and his brother Bob jobs doing survey work in the Yukon. This was in support of government plans to establish domestic reindeer herds to support the Inuit communities of the Yukon and Northwest Territories – and the source of the book's title. Dathan's presentation of this period presents one of the highlights of the book. The Porsild brothers spent several years in the northwest. They travelled across the North Slope of Alaska by dog sled in the dead of winter, followed by further adventures in boats, canoes and on foot. This would make for gripping reading as a simple tale of adventure travel. But of course, in addition to all the work involved in living a mostly self-sufficient life in the often brutal Arctic, the two brothers dutifully collected and pressed specimens throughout their journeys.

This work established Erling in Canadian botany. However, it would be many years before he finally secured a permanent position with the National Museum. He eventually became the Chief Botanist for the institution, but only after years in short-term or acting positions.

All the while, he continued to pursue his scientific work. Through Porsild's struggles to have his work published, Dathan explores his relationships with his contemporaries, including Oscar Malte, Hugh Raup, Merritt Fernald, and especially the Swedish botanist Eric Hultén. Hultén and Porsild were both working on northern floristics, and for years Porsild saw the Swede as a competitor. Many years later they reached a reconciliation of sorts, with Porsild realizing that both of their work had suffered from lack of cooperation. This was a very compelling story, and another highlight of the book for me.

For those of us that grew up with Farley Mowat's stories, the chapter covering the heated dispute over Mowat's contentious book, "People of the Deer" is also very interesting. Porsild, along with many other Arctic researchers, found Mowat's claim that his book was a factual retelling of actual events too fantastic to believe. Unfortunately for Porsild, he put his objections in print. The ensuing dust-up consumed far more time and energy than Porsild would have liked, particularly for a book he felt had such little merit.

Dathan's book is a truly monumental effort, and a great service to the botanical community of Canada. Indeed, she has received awards from the Alberta Book Awards and the Canadian Historical Association. Her writing is clear and understated – she provides very little commentary of her own. Instead, as far as possible, she lets Erling tell his own story, with extensive quotations from his correspondence. For the most part, this is very effective.

That said, I do have to take issue with one aspect of her work – at 726 pages, I frequently wished she'd been

more willing to omit the less interesting details of Porsild's life. Every time a boat engine broke, or a trip was delayed, we read about it, and in far more detail than necessary. A few of these embellishments add colour to the story. But after 500 pages, a little restraint would have been appreciated!

In summary, I can highly recommend this book to anyone interested in the history of exploration in Cana-

da. As a plant taxonomist, I found it provided a fantastic, and at times jaw-dropping, look at the challenges and triumphs of one of our scientific forebears. And of course, this should be required reading for Canadian botanists!

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Alexander Wilson, the Scot who founded American Ornithology

By Edward H. Burt, Jr. and William F. Davis, Jr. 2013. The Belknap Press of Harvard University Press, Cambridge, MA, USA, 02138. 464 pages, 35.00 USD, Cloth.

Alexander Wilson is considered the Father of American Ornithology but he is little known outside the bird world. The year 2013 marks the 200th anniversary of Wilson's death and 2014 marks the 200th anniversary of the completion of *American Ornithology*. The timing is perfect!

When an infant, Alexander Wilson was christened by Dr John Witherspoon, who later became president of the College of New Jersey, the forerunner of Princeton University. Nicknamed "Sandy," he attended Latin-Grammar School in Paisley, Scotland. He was apprenticed as a weaver, but established a reputation as a poet (one anonymous poem sold 100,000 copies) and a labour activist.

In 1794, at age 28, Wilson sailed for Philadelphia, never to return. In 1801, as a teacher in Milestown, Pennsylvania, he wrote a widely published poem, "Oration," to celebrate the inauguration of President Thomas Jefferson. The "watershed event" of his life was his move in 1802 to Kingessing at Gray's Ferry, close to the home and garden of naturalist John Bartram, who became his constant source of encouragement. In 1804 Wilson was appointed assistant editor at the Bradford and Inskeep publishing house in Philadelphia. By 1808 Wilson was able to publish volume 1 of his own *American Ornithology*, followed by volumes 2 in 1810, and volumes 3 through 7 before he died suddenly of dysentery at age 47 on 23 August 1813. After his death, Volume 8 was seen through the press and Volume 9 put together by George Ord in 1814.

Within their longest chapter (three, pages 63 through 279), Burt and Davis provide a detailed explanation of Wilson's artistic progress from a novice illustrator into an accomplished artist: from previously unavailable pencil sketches through pen and ink drawings, and then from draft paintings to the final product, each plate individually coloured by hand. Wilson broke with the 18th-century tradition of portraying single birds sitting on miniaturized trees and began painting multiple species with naturalistic backgrounds, in poses that facilitated identification. This chapter should be of great interest to artists as well as ornithologists. Wilson laid the groundwork for future artist-naturalists, especially

John James Audubon, whom Wilson first met in 1810 in Louisville, Kentucky, where they hunted birds together and parted amicably.

Wilson's friendship with George Ord began with their joint trips to Cape Cod in 1811. Although Ord, unlike Wilson, despised Audubon, I especially enjoyed reading two anecdotes about Ord: 1) "Ord cannot resist attacking Audubon. Beginning with a rude reception on an April evening in the Philadelphia Academy of Natural Sciences, Ord's intransigence and Audubon's ego led to increasingly bitter accusations of plagiarism on both sides until, tragically, Wilson's accomplishment was lost in the haze of charge and counter-charge..." 2) The account of George Ord's surprise to learn, when Wilson died, that he was not wealthy but lived in one upstairs room, died owing money, and had a library consisting of only two books. Although Wilson wrote long and detailed travel letters and kept meticulous records of the birds he shot, Wilson's accurate accounts of bird behaviour were largely written from memory."

Burt and Davis explain that Alexander Wilson was the first to have five species named for him (page ix); spend all his time studying birds (page 285); produce a formal classification of American birds within the Linnaean system (page 333); document seasonal change in avian testis size (page 316); provide anatomical detail of feathers and foot scale patterns (page 351); recognize citizen science (page 320); introduce quantification of the economic effects of birds (page 330); explore dietary and morphological detail by dissection (page 333); use behavioural, ecological and quantitative observations (page 333); and successfully underwrite a large publishing project based on subscriptions from largely middle-class individuals (page 333). *American Ornithology* was the first major scientific work published in the United States. Wilson's nine volumes established American scientific ornithology, set a new standard for scientific description, and elevated nature writing to a distinctly American tradition (page 333).

On occasion, I would have welcomed a little more detail, perhaps in end notes if not in the text, explaining to today's readers that the Black-bellied and Semi-

palmed Plover bred in Wilson's time in not-yet-discovered Arctic regions, making clear that Wilson had observed the injury-feigning of the Piping, not the Semipalmated, Plover.

I would also mention that "many," not "most," of the new bird names originated from Linnaeus (page 83); that Steller's 'Kampsehatlea' refers to present-day 'Kamchatka' (page 128); that the Willet nests on dry ground (page 280); and that *Philosophic Transactions* was one of the first two scientific journals in the world (page 381).

Wilson's skills as a writer, a taxonomist and especially as an observer of bird behaviour. Readers will accept this book's evidence that Wilson's nine volumes were of even greater importance than those of Audubon. The cost is below that of similar books and should result in the first printing of five thousand copies requiring a reprint within a year. It deserves to sell steadily for twenty more years.

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned

Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros, AUD Australian Dollars.

ZOOLOGY

The Urban Bestiary: Encountering the Everyday Wild. By Lyanda Lynn Haupt. 2013. Hachette Book Group, 237 Park Avenue, New York, NY, USA, 10017. 337 pages, 30.00 CAD, Cloth.

The American Crow, Naturally. By Tom Reaume. 2013. Winnipeg, MB, Canada, Self-published ebook. 715 pages on 16 PDFs may be printed for free at [*tom4crows.com](http://tom4crows.com).*

* **The Cougar.** By Paula Wild. 2013. Douglas & McIntyre Publishing Group, Suite 201, 2323, Quebec Street, Vancouver, BC, Canada, V5T 4S7. 304 pages, 34.95 CAD, Cloth.

* **Enter the Realm of the Golden Eagle.** Edited by David H. Ellis. 2013. Hancock House Publishers Ltd., 19313 Zero Avenue, Surrey, BC, Canada, V3S 9R9. 496 pages, 60.00 CAD, Cloth.

* **Looking for the Goshawk.** By Conor Mark Jameson. 2013. Bloomsbury Publishing Inc., 385 Broadway, New York, NY, USA, 10018. 368 pages, 18.99 GBP, Cloth.

* **Primates of the World – An Illustrated Guide.** By Jean-Jacques Petter and François Desbordes (Translated by Robert

Martin). 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 186 pages, 29.95 USD, Cloth.

OTHER

* **Landslide Ecology – Part of Ecology, Biodiversity and Conservation.** By Lawrence R. Walker and Aaron B. Shiels. 2013. Cambridge University Press, 32 Avenue of the Americas, New York, NY, USA, 10013-2473. 300 pages, 54.00 USD, Paper.

The Peace-Athabasca Delta: Portrait of a Dynamic Ecosystem. By Kevin Timoney. 2013. University of Alberta Press, Ring House 2, Edmonton, AB, Canada, T6G 2E1. 608 pages, 160.00 CAD, Cloth or 90.00 CAD, Paper.

Telling Our Way to the Sea – A Voyage of Discovery in the Sea of Cortez. By Aaron Hirsh. 2013. Roberts and Company Publishers, 4950 S. Yosemite Street, F2 #197, Greenwood Village, CO, USA, 80111. 416 pages, 28.00 USD, Paper

* **The Once and Future World – Nature As It Was, As It Is, As It Could Be.** By J. B. Mackinnon. 2013. Random House of Canada Limited, 75 Sherbourne Street, 5th Floor, Toronto, ON, Canada, M5A 2P9. Not illustrated. 272 pages, 29.95 CAD, Cloth.

News and Comment

Using Coefficients of Conservatism and the Floristic Quality Index to Assess the Potential for Serious and Irreversible Damage to Plant Communities

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Catling, Paul M. 2013. Using Coefficients of Conservatism and the Floristic Quality Index to assess the potential for serious and irreversible damage to plant communities. *Canadian Field-Naturalist* 127(3): 285–288.

Coefficients of Conservatism and the Floristic Quality Index can be used to assess potential damage to plants and plant communities as a result of anthropogenic disturbances. This has benefit because it may be more powerful than an opinion and more easily understood and trusted by non-botanists and land use decision-makers.

Key Words: Coefficient of Conservatism; Floristic Quality Index; serious and irreversible damage; disturbance; plants; intolerant

In making a decision about what kinds of activities are to be permitted in a natural area, a landowner or land manager may have to decide whether or not the activity will result in “serious and irreversible damage” to a plant community. A botanist is usually invited to give advice on the matter, which often comes in the form of a professional opinion. The first consideration is what the phrase “serious and irreversible damage” really means. “Serious” may be taken to mean causing a relatively large change or harm to the individuals of the plant species present. The meaning of “irreversible” is clear. Thus the phrase refers to a large change that cannot be undone.

The second consideration might be whether or not there is anything that can be provided that would be more useful than an opinion. Of course an opinion based on a great deal of knowledge and personal experience has immense value. However, non-botanists may have some difficulty understanding this value or may perceive bias in the opinion. What can be brought to supplement it? Here I discuss an approach that I found beneficial in this context.

Different species of plants and kinds of plant communities vary in their susceptibility to damage or harm and this can be measured with Coefficients of Conservatism and the Floristic Quality Index. These metrics provide a way of assessing potential impact that might prove useful to biologists providing advice.

The concepts of Conservatism and the Floristic Quality Index

The Floristic Quality Index (FQI) of a site is based on native floristic diversity and some of the components of rarity (in the broad sense) of the native species present. It was first developed as a method of identi-

fying natural areas and evaluating sites for protection (Swink and Wilhelm 1994, Wilhelm and Masters 1995, Bourdaghs et al. 2006) and is now widely used along with other criteria for this purpose (Bried et al. 2012). It can also be used to establish goals of restoration (Spyreas et al. 2012), to monitor the success of restoration (McIndoe et al. 2008), evaluate management practices (Smart et al. 2011), to assess human impacts on an area (Bourdaghs et al. 2006) and to evaluate ecological (community) integrity (Nichols et al. 2006).

The FQI is the square root of the number of native species present in an area multiplied by the average Coefficient of Conservatism (CoC) for the native species present. A square root enables diversity to be considered without being weighted too heavily. The coefficients are assigned for species of native vascular plants within a particular geographical area such as southern Ontario (e.g., Oldham et al. 1995). Higher values of the coefficients of conservatism, on the scale of 1–10, indicate species that are more “conservative” (or ecologically sensitive), including those least associated with anthropogenic disturbance, least aggressive, least able to spread, and most confined to particular natural habitats. Common Milkweed (*Asclepias syriaca*), which most people have seen along roadsides and in meadows, has a CoC of “0” while the endangered Prairie White Fringed-Orchid (*Platanthera leucophaea*), which is very sensitive to invasives and human activity leading to the drying of fens, has a CoC of “10”.

Oldham et al. (1995, page 4) explain conservatism succinctly: “The native plant species of any particular area vary in their degree of tolerance to disturbance, and display varying degrees of fidelity to specific habi-

tats. Species conservatism, – the degree of faithfulness a plant displays to a specific habitat or set of environmental conditions, – is the basis for this premise. The natural quality of an area is reflected by its richness of conservative species (Wilhelm & Ladd 1988).” Oldham et al. (1995 page 7) explain the process of ranking plant species:

“Each native taxon was assigned a rank of 0 to 10 (“coefficient of conservatism”) based on its degree of fidelity to a range of synecological (community) parameters. Plants found in a wide variety of plant communities, including disturbed sites, were assigned ranks of 0 to 3. Taxa that typically are associated with a specific plant community, but tolerate moderate disturbance, were assigned ranks of 4 to 6. Rankings of 7 to 8 were applied to those taxa associated with a plant community in an advanced successional stage that has undergone minor disturbance. Those plants with high degrees of fidelity to a narrow range of synecological parameters were assigned a value of 9 to 10. ... In order to use the method to evaluate a site, a species list is compiled, and the coefficients of all native plants are summed and divided by the total number of native plants to yield a mean coefficient for all the native plants in the assessment area. A “Natural Area Index” (also called a Floristic Quality Index) can be calculated by multiplying the mean coefficient by the square root of the total number of native species. Natural areas can be compared using their mean coefficient and/or the Natural Area Indices.”

Bried et al. (2012 page 101) note that: “the foundation of the index is the conservatism concept, which estimates a species’ ecological sensitivity or propensity to occur in areas least altered by humans. Plant species are assigned coefficients of conservatism where ruderal species receive the lowest scores, competitors and matrix species intermediate scores, and remnant dependent species the highest scores. ... The concept is loosely allied with the competition-stress-disturbance model of plant ecology (Grime 1974), and therefore derives from colonization and survival strategies and adaptation to post-disturbance successional stages (Bowles and Jones 2006, Taft et al. 1997). Species with high conservatism values are sensitive to anthropogenic stress and therefore restricted to minimally altered natural areas ..., whereas species with lower values are most likely to persist in or readily invade degraded areas (Spyreas and Matthews 2006).”

These explanations, and others, include the idea that some species and some communities are more ecologically sensitive than others. The use of the words “conservative” and “conservatism” are not only refer-

ences to rarity but also representative of a number of biological features that correspond to a scale of tolerance to change.

Relation to “serious and irreversible damage”

If several native plants are eliminated from a community and many others are killed, then large change and “serious” damage has occurred. Persistence, reinvasion and purposeful restoration may enable this damage to be undone to some extent. All three possibilities are related to characteristics of CoC. Reinvasion and succession are often long processes and because the sources of plants and interactions and geological history that led to occurrence in a particular place are not necessarily going to be repeated, re-colonization is uncertain and perhaps in many cases unlikely. Likelihood is also decreased as a result of changes in climate and/or the landscape. Persistence depends on the amount of change and the ecological sensitivity of the plants. If the latter is high, then restoration will be less likely.

For simplicity, the term “restoration” will be used subsequently to include any kind of restored (with or without purpose) species or species group. If restoration is impossible or very unlikely then the damage may be “irreversible.” What makes restoration unlikely, under certain circumstances, is high ecological sensitivity. Any species with a high CoC that is intolerant to change (ecologically sensitive and occurs only in habitats least altered by humans) will be the least likely to be capable of restoration in the damaged habitat. Likewise any plant community with a relatively high FQI (based on high average CoC and high diversity) will also be less likely to be capable of restoration. Thus both CoC and FQI can be used to assess the likelihood of successful restoration. It is to be noted that successful restoration of a few species does not constitute successful recovery of a community or ecosystem.

Many factors

The greater the number of factors such as competition with invasive species, continuing destruction, substrate characteristics, etc., that influence restoration, the more difficult it is likely to be. Where water plays an important role, as ground water or surface flow does on alvars and in fens, the likelihood of successful restoration is lower because any disturbance to the habitat is likely to affect both water flow and chemical composition (in addition to other potential factors). This can be an unfortunate combination for relatively intolerant plants that require low nutrient status and well defined natural flow regimes. These other factors are accounted for, to a degree, in the biological limitations of the plants and communities in general reflected in CoC and FQI values. However, it is helpful to have some kind of damage in mind in order to be able to say that it will, or will not, be irreversible, because CoC and FQI are not necessarily indicators of the likelihood of all restoration under all circumstances of disturbance. It is also necessary to distinguish natural processes (or dis-

turbances) that may be beneficial, from anthropogenic disturbances that are likely to be (but are not always) detrimental.

Kinds of disturbance

The most destructive changes to plant communities are often those accompanying major developments. The construction of buildings and structures causes long-term or permanent loss of habitat. There may also be very extensive damage to adjacent areas due to the construction of crane pads, crushing of vegetation and compaction of substrates by heavy equipment, as well as ruts in parking areas, working areas, storage areas and temporary roads. Construction vehicles contaminate substrates with toxic materials including oil and lubricants, introduce material from other sites, and introduce seeds and vegetative parts of competing invasive alien plants. Bulldozing, scraping, and dumping of fill alters the habitat. Although changes to water movement as a result of construction may have far-reaching effects on plants, they would not be revealed in the standard evaluations that consider only fish.

Other seemingly benign changes to land use may cause destructive damage, such as over-grazing, which includes compaction and nutrient addition, trampling, cultivation, drift of pesticide and herbicide from adjacent areas and succession as a result of loss of natural processes. Competition with invasive alien species may also be a major concern. To a degree the CoC and FQI are likely to correctly predict a response in the plant community to any of these kinds of disturbances.

Conclusions

When explaining the likelihood of serious and irreversible damage to plants and plant communities, a simple methodology may be more appreciated and more trusted than an opinion. One has to remember that non-botanists do not have the experience to understand how opinions were derived, but they do often have the last call on what happens to a botanically-significant landscape. There is an important role for Coefficients of Conservatism and the Floristic Quality Index in this regard because they are easily understood and reliable. The coefficients, which enable the index, are developed by a panel of experts, so they are trusted.

The CoC and FQI do not enable one to demonstrate an amount of damage with absolute certainty, but they do provide an objective method of applying a range of likelihood that is based on widely used concepts. In some cases their use may enable a sufficient degree of probability to be demonstrated to result in the protection of a natural area. In many cases it will be the best that can be done to support an idea that "serious and irreversible damage" to a plant community is likely.

Although now well-known and widely employed to evaluate plant communities for a variety of purposes in the United States, the coefficient and the index are not well known and rarely employed in many parts of Canada. Their use to support an opinion by predicting

the likelihood of serious or irreversible damage is just one of many potential and related uses.

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Received 23 May 2013

Accepted 1 August 2013

Revisions to the OFNC Constitution and By-Laws

This notice is to officially inform the members of The Ottawa Field-Naturalists' Club that the Constitution and By-laws of the club are going to be revised over the next year.

This review is necessitated by changes to the Ontario Not-for-Profit Corporations Act (ONCA). Although the act was passed in 2010 it has not yet been proclaimed to make it come into force. There have been several delays but now it is looking like January 2014 is the target date. After that we have three years to modify our constitution and by-laws to conform to this new legis-

lation or they will be deemed to have been modified.

Those of you who attended the Annual Business Meeting in January, 2013 have heard of this pending project. We are just in the early stages of determining the impact on our Club. However, it is certain that changes will be needed to conform to the ONCA. While we are reviewing our constitution and by-laws for the new legislation we will also consider any other changes needed to reflect the reality of today. The last time the constitution and by-laws of the Club were up-dated was February 2000.

Upcoming Meetings – The Society for Integrative & Comparative Biology Annual Meeting 2014

The Society of Integrative and Comparative Biology (SICB) annual meeting to be held 3–7 January 2014 in Austin, Texas. Presenter registration deadline is 8 No-

vember 2013 and early fee deadline is 6 December 2013. More information is available at <http://www.sicb.org/meetings/2014/>.

Minutes of the 134th Annual Business Meeting of The Ottawa Field-Naturalists' Club January 15, 2013

Place and time: Fletcher Wildlife Garden, Ottawa, Ontario, 7:00 pm
Chairperson: Ann MacKenzie, President

Attendees spent the first half-hour reviewing the minutes of the previous ABM, the Treasurer's report and the OFNC committees' annual reports for 2011. The meeting was called to order at 7:30 pm with some opening remarks from the President.

Over 30 attendees spent the first half-hour reviewing the minutes of the previous ABM, the Treasurer's report and the OFNC committees' annual reports for 2012. The meeting was called to order at 7:30 pm with some opening remarks from the President.

1. Minutes of the Previous Annual Business Meeting

It was moved by Annie Bélair and seconded by Diane Lepage that the minutes of the 133rd Annual Business Meeting be accepted as distributed.

Carried

2. Business Arising from the Minutes

Nil.

3. Communications Relating to the Annual Business Meeting

Nil.

4. Treasurer's Report by Ken Young

This is my first year as Treasurer, and it is been a learning experience the entire time.

I would like to thank my predecessor, Frank Pope, for showing me the ropes and providing invaluable advice throughout the year. As well, Yi Zhang performed a number of duties before moving to Calgary, making the first six months much easier. Ann MacKenzie continues to keep track of our investments. Finally, Wendi Mosher and Andrea Armstrong of Mosher Bookkeeping and Mark Patry and Eric Liebmann of Welch LLP have provided able professional assistance to the Club.

Changes to the Financial Statements

We have made some changes to the financial statements.

First, new accounting standards have been established for not-for-profit organizations and we have adopted them. The new standard actually simplifies the preparation of our accounts, since we no longer have to calculate a notional "fair-market" value for the bonds that we hold as investments.

Second, we are now showing our major activities on a gross rather than a net basis. This affects three of our activities that have significant revenues and expenses – the Canadian Field-Naturalist, the Fletcher Wildlife Garden and the Pelee trip. Instead of showing a single figure for net revenues or expenses in the General Fund statement (page 3), we show gross revenues in the Revenue section and gross expenses in Activity Expenses.

This year, we are not showing any detailed breakdown of revenues and expenses of these activities. In the case of the CFN, the results for the 2011 and 2012 fiscal years require so much interpretation that it would be misleading to present them in the traditional way.

General Results for the Year

Assets are up 5%, reflecting the excess of revenue over expenses this year of \$30,920.

Revenues held quite steady. There were higher, but mainly because we held a Pelee trip in 2012 but not 2011.

On the other hand, expenses declined significantly.

Operating expenses were down 31% and activity expenses were 14% lower. This is what we want – our mandate is generally served by spending money on activities.

CFN expenses were down significantly. This reflects a number of factors. One is that we simply published fewer issues in 2012. However, the move to electronic publication has reduced our printing and circulation costs.

Fletcher Wildlife Garden expenses were sharply up. This reflects the success of the Garden volunteers at raising and spending money for special projects. Most recently, they received a grant of \$17,000 to create a Monarch Waystation, and most of this money was spent in FY2012. It is important to emphasize that this successful fundraising was not accidental, but resulted from hard work and perseverance.

Looking Ahead

I expect that the current (2013) fiscal year will be uneventful from a financial point of view.

This fiscal year will continue the catch-up process for the CFN, which could result in five or six issues being published by the end of September. However, the move to digital publication has been successfully accomplished so there should not be any financial surprises.

The Wildlife Garden will complete the work on the Monarch Waystation.

As a provincially-incorporated organization, the OFNC is governed by Ontario corporate law. This is changing. Ontario has passed a new Not-for-Profit Corporations Act and is expected to proclaim it, and publish associated regulations, sometime this year. When that happens, a committee will be formed to examine its provisions, and make recommendations to bring our by-laws and procedures into conformity. Some of our financial practices may be affected.

We have been advised by our reviewer to consider the best way to account for donations and grants that are earmarked for a specific purpose. An example is the Monarch Waystation grant. We will examine this issue and any changes will be implemented in our next financial statements.

Council has authorized the Birds Committee to do the planning for a new Birds Checklist, which could involve significant expenditures.

The OFNC will be helping Nature Canada with the Lac Deschênes Important Bird Area (IBA) and the BirdLife World Congress 2013, which could result in significant expenditures.

Motion: It was moved by Ken Young and seconded by Frank Pope that the financial statements be accepted as a fair representation of the financial position of the Club as of September 30, 2012.

Carried

5. Committee Reports

The annual committee reports serve as a record of what the OFNC does throughout the year. A copy had been distributed to attendees at the beginning of the meeting; Ann asked if there were any questions or comments.

Eleanor Zurbrigg asked if a list of the committee members should be included with each committee report. Ann answered that since committee rosters are published in *Trail & Landscape*, it is not necessary to include them in the annual reports.

Moved by Annie Bélair and seconded by Diane Kitching that the reports be accepted as distributed.

Carried

6. Nomination of the Financial Reviewer

Moved by Ken Young and seconded by Frank Pope that the accounting firm of Welch LLP be nominated to conduct a review of the OFNC's accounts for the fiscal year ending September 30, 2013.

Carried

7. Report of the Nominating Committee D. Hobden

Slate proposed by the nominating committee:

NOMINATIONS FOR OFNC COUNCIL 2013

Officers

President	Fenja Brodo
1 st Vice President	Vacant
2 nd Vice President	Jeff Skevington
Recording Secretary	Annie Bélair
Treasurer	Ken Young

Council Members

Dan Brunton	Carolyn Callaghan
Barbara Chouinard	Owen Clarkin
Barry Cottam	Ian Davidson
Don Hackett	David Hobden
Diane Kitching	Diane Lepage
Ann MacKenzie	Karen McLachlan Hamilton
Lynn Ovenden	Remy Poulin
Henry Steger	Eleanor Zurbrigg

Motion: Moved by David Hobden and seconded by Marilyn Ward that this slate of nominees be accepted as members of the Council of the OFNC for 2013.

Carried

Ann stated how much she had enjoyed being President of the OFNC for the past three years and thanked the team of Council members for all their support. She also said how pleased she was that Fenja Brodo would be the new President. Fenja knows the club very well from all her past years of service to the club and Ann is confident that she will make an excellent President.

8. New Business

1. The OFNC noted with sadness the passing during 2012 of three members who had made a notable contribution to the club and the naturalist community:

a. Donald Britton – died this May – Honorary Member (2001) – University of Guelph professor and internationally recognized fern expert; a tribute appearing in the next issue of the CFN.

b. Enid Frankton – died this May – long time member (since 1948) and active in field trips, the Awards Committee and conservation activities.

c. Laurie Consaul – died December 18, 2012 – arctic botanist at the Canadian Museum of Nature and keenly involved in eastern Ontario activities of the Ontario Breeding Bird Atlas.

2. Revisions to the Ontario Not-For-Profit Legislation:

Ann explained that when the new act comes into force, the OFNC will have three years to modify its bylaws and constitution accordingly. It is also a great opportunity to update the constitution in general. A committee will be created; anyone who is interested in participating can contact Ann MacKenzie at annmackenzie@rogers.com. The committee will report back at the 2014 ABM.

9. Adjournment

Moved by Diane Lepage and seconded by David Hobden that the meeting be adjourned at 8:45 pm.

Carried

ANNIE BÉLAIR
Recording Secretary

The Ottawa Field-Naturalists' Club 2011-2012 Annual Reports

Awards Committee

The Awards Committee met in February 2012 to select deserving recipients for the Club's awards for the year 2011. Committee members evaluated nominations received against the criteria for each of the awards (see <http://www.ofnc.ca/awards.php>) and then selected the nominees who best fit the criteria; in all, five nominations were presented to and approval by Council. Awards Committee members prepared the citations for each award recipient which outlined the many ways in which the person had distinguished herself or himself by accomplishments in the field of natural history and conservation, or by extraordinary activity within the Club. The awards were presented at the Club's annual Soiree in April.

ELEANOR ZURBRIGG, Chair

Birds Committee

The Birds Committee organized the Fall Bird Count and along with the Club des Ornithologues de l'Outaouais participated in the 2011 Christmas Bird Count. The annual Peregrine Falcon Watch had an interesting year. Although the downtown nest was a failure for the 3rd year in a row, another nest was found on a government office building in Ottawa south. The Falcon Watch group was on site and two chicks fledged successfully. The building management is in discussion with the Falcon Watch and the Ministry of Natural Resources about erecting some type of nest box for next season. The Bird Record Subcommittee met during the year to review rare bird reports and is working on a new checklist for Ottawa. The committee also has a liaison with Bird Life International for their upcoming conference in 2013 and with Nature Canada for the Lac Deschênes Important Bird Area (IBA).

CHRIS TRAYNOR, Chair

Conservation Committee

For most of 2011/12 there was no formal conservation committee because the previous chair, Ken Young, had moved to the position of Treasurer. In October 2012 Owen Clarkin agreed to chair the committee. However, during the year there was a Google Group of members interested in conservation issues and they considered various issues that arose. The activity of this group prompted the club to join other naturalist clubs in Ontario in urging the Ontario government to ban the hunting of snapping turtles. As usual there were a number of articles in *Trail & Landscape* throughout the year on conservation related topics. On October 3rd there was a discussion at the Fletcher Wildlife Garden on the Ottawa Forests and Greenspace Advisory Committee. In November, the newly re-constituted Conservation Committee sought the support of Council to oppose the extension of cottage leases in Algonquin Park. A letter was sent to the Minister along these lines.

ANN MACKENZIE

Education & Publicity Committee

We have eight members on this committee, Ann Prescott, Jeewa Mendis, Susan Barker, Suzanne Deschêne, Gillian Marston, Lynn Ovendon, Mark Brenchley and Fenja Brodo. Two are relatively new members (Lynn and Mark) and two (Gillian and Suzanne) are only here part of the year but give substantial assistance when they are in town.

This committee staffs our monthly table with saleable items, responds to requests for walks and talks by groups outside our Club and represents our Club at various natural history events in the Ottawa region having anything to do with natural history. Ann Prescott ably staffs our sales table. We have recently added Club lanyards (designed by Mark Brenchley) with hand lenses attached that have been selling well. Mark also designed and made a colourful Club banner that can be used for both indoor and outdoor display areas.

The Science Fair was ably staffed once again by Jeff Skevington and Carolyn Callaghan.

We had our Club display set up at the following venues: Jack Pine Trail, 21 May, on our own initiative to advertise our Club; Sept 29 as participants at the Larose Forest Day; 3 November, at Mud Lake, advertising the Lac Deschênes IBA.

We filled the following requests for leaders as detailed below:

- Jane's Walk at Browns Inlet with an emphasis on water and air quality, Sunday May 6th, with lichenologist Irwin Brodo and phycologist Paul Hamilton.
- Urban Walks: Flutterings: Night Moths and other Insects, Saturday evening June 2nd, with Diane Lepage and Fenja Brodo. (Cancelled due to bad weather).
- Day Camp, Dempsey Community Centre, Thursday July 12th. A program on insects with Miriam Tepper and Fenja Brodo.
- AJA 50 + Nature walk, Gatineau Park Friday, August 10th, Irwin & Fenja Brodo (Cancelled due to bad weather).

This year there was no Wildlife Festival for us to participate in.

Excursions and Lectures Committee

Over the course of 2012, the excursions and lectures committee coordinated 42 hikes, four workshops, eight monthly meetings and the annual business meeting. The hikes and workshops covered a wide breadth of topics, including: general natural history (14), birds (13), insects (6), plants (5), amphibians (3), geology (2), mammals (1), fish (1) and fungi (1). In addition to bringing back many tried and true events and leaders, several new events were tried. New events included a Cranberry Crawl, a canoe trip to Ottawa River Duck Islands, an insect photography workshop, a larval dragonfly and damselfly outing, and eBird and insect identification workshops. Fenja Brodo coordinated our popular Pelee and Rondeau trip that was once again well attended and produced some great birding highlights. Monthly meetings continued to be held in the Museum of Nature and included talks on birds (4), insects (1), plants (1) and ecology (2). Committee members included Rob Alvo, Holly Bickerton, Fenja Brodo, Julia Cipriani, Hume Douglas and Jeff Skevington (chair). If you have any new ideas for events or would like to be a leader, please contact Jeff (jhskevington@gmail.com) or other members of the committee.

JEFF SKEVINGTON, Chair

Finance Committee

As a result of the major financial changes in the previous fiscal period, the Finance Committee now sees the benefits to the club: in improved account reporting; timely financial reports such as quarterly statements; and specific reports on request, such the CFN information by issue. This is very helpful to the Council and committees.

The Finance Committee met several times during this fiscal year to discuss several issues that were brought forward. Topics discussed were: the Chart of Accounts where accounts were modified for better reporting; a possible CFN endowment fund campaign; and the financial reporting in respect of CFN. The reporting of CFN in the financial statements was on an ongoing issue over the period with discussions at the Finance Committee meetings and with council. The OFNC consulted with its auditor on the possible solution and the club will proceed with the auditor's advice. For the next fiscal period, the direct CFN revenues will be included with the other Club revenues. CFN expenses will be shown in total with the other committee's expenses with more detail provided in a note.

The club is continuing to run a deficit. However the long term goal in respect of finances for the club is a balanced budget and the financial information for this year indicates that the OFNC has improved marginally on its financial situation. While there is a net surplus for fiscal 2011/12 some of this relates to the subscription revenue for Vol. 126 having been received while the expenses are not yet incurred since only Vol. 126(1) had been issued by fiscal year-end.

Fiscal Responsibility continues to be the objective for the Finance Committee's. With an improving financial situation, the club will be able to look toward other objectives beyond the club's normal operations. For example, the use of the club's legacy funds to undertake new projects as per the OFNC objectives to promote, conserve and appreciate Canada's natural heritage.

BARBARA CHOUINARD, Chair

Fletcher Wildlife Garden

The Fletcher Wildlife Garden has had a successful, although unusual year with much more of our effort devoted to areas other than the Backyard Garden. The Backyard Garden continued to be maintained and developed by our Friday morning volunteer group. It now has a second bench as well as a new picnic table. We were able to use the watering system during the summer so the drought had little effect there. We also purchased a new mower and a new shed to keep it and the garden tools in.

On Saturday, June 2, the annual native plant sale, featuring plants we grow ourselves and donations, raised over \$4500 despite poor weather on the day.

Control of invasive species has increased, thanks to efforts by our invasive species group as well as work by some members of the Friday morning volunteers and the Butterfly Meadow group. We were able to completely remove some larger trees and replace them with native trees and shrubs. We have put a lot of work into Dog-strangling vine (DSV) control with limited success. We are hoping the FWG might become a test site for a new biocontrol agent — a moth from the Ukraine.

In 2010, the FWG submitted a proposal to the Evergreen Foundation to turn the site into a monarch butterfly waystation and to create a smaller model waystation in the Butterfly Meadow. The proposal won second place in a competition to fund environmental improvement projects that Evergreen ran for the Fido phone company. We received the prize late in 2011 and prepared plans over the winter.

Over 3000 plants, which we grew ourselves, purchased or had grown by Budd Gardens from seeds we supplied, were planted and maintained through the summer. We have purchased a bulletin board and leaflet box for public education. It will be erected next year. An OFNC monthly meeting on monarch butterfly biology was sponsored using our waystation funds.

To engage more volunteers, we organized Sunday morning work groups, primarily to remove DSV. This attracted several students looking to fulfill community service requirements. We were also helped by several corporate groups who planted trees and shrubs in the ravine and perennials in the Butterfly Meadow and helped with DSV removal. These groups often provide funds to support the project they work on, so we derived significant income from that source. Late in the season, an environment class from Carleton U helped clear invasives and replant a birch grove.

FWG is online with a web site connected with the OFNC site, providing information on wildlife gardening and the animals and plants at the FWG. We also produced eight newsletters this year and maintained photo galleries and a blog, thanks to many volunteers.

DAVID HOBDEN,

Member of the Fletcher Wildlife Garden Committee

Macoun Field Club Committee

The Committee planned the month-to-month program by telephone and e-mail, and maintained an up-to-date schedule on its website (macounfieldclub.ca). Committee members supervised or gave presentations at 19 indoor meetings and led 17 field trips during the school year. Indoor sessions were held in the Fletcher Wildlife Garden building. Most field trips took place either at the Club's nature-study area in Ottawa's Greenbelt or on private properties in Lanark County; two were held jointly with the OFNC. The Committee presented its current Field Trip Policy and outline of field-trip practices to OFNC Council for approval, and published them in Issue no. 66 of *The Little Bear*. A 350-page compilation of all *Little Bear* articles on the Macoun Club's nature-study area was prepared and bound in hard-cover, to bring all observations, inventories, and studies across the past 42 years together in one place.

ROBERT E. LEE, Chair

Membership Committee

The distribution of the membership for 2012 on September 30, 2012 is shown in the table below, with the corresponding numbers for 2011 shown in brackets. "Others" represent, for the greatest part, affiliate organizations that receive complimentary copies of the Club's publications. The decrease in total membership of 1 is a result of new memberships essentially balancing non-renewing members. Local membership (within 50 km of Parliament Hill) increased to 633 from 621 in 2012 and 2011, respectively, in keeping with the continuing trend in decreasing membership outside the 50 km Ottawa area.

HENRY STEGER, Chair

	CANADIAN		USA		OTHER		TOTAL	
	2012	2011	2012	2011	2012	2011	2012	2011
Individual	351	(361)	13	(13)	0	(0)	364	(374)
Family	285	(282)	1	(1)	1	(1)	287	(284)
Student*	10		0		0		10	
T and L	3	(2)	0	(0)	0	(0)	2	(2)
Honorary	21	(24)	0	(0)	0	(0)	21	(24)
Life	47	(48)	3	(4)	1	(1)	51	(54)
Other	23	(23)	0	(0)	1	(1)	24	(24)
TOTAL	740	(740)	17	(18)	3	(3)	760	(761)

*Student Membership was initiated in Year 2012 and is intended to encourage interest in natural history among high school and university students.

Publications Committee

The Publications Committee, consisting of Carolyn Callaghan, Paul Catling, Jay Fitzsimmons, Sandra Garland, Tony Gaston, Karen McLachlan Hamilton, Elizabeth Morton, Frank Pope and Jeff Saarela (and Dan Brunton, Chair), met formally three times through the year to discuss a wide variety of issues and to provide advice and information to both the OFNC Council and to the editorial teams who actually do the majority of this work. One of these meetings was held at the west Quebec home of Canadian Field-Naturalist Editor-in-Chief Callaghan. Business was conducted only after we'd enjoyed a hearty meal and a productive ramble in woodlands and fields that turned up several rare natural history observations. We are all naturalists, after all. Other issues were dealt with periodically through individual conversations or by electronic communications.

If the biggest publication challenges for 2011 were to survive the transition of The Canadian Field-Naturalist to a predominantly digital format and getting closer to a regular release schedule, the main challenges for 2012 were to sustain that momentum and to make plans for the long-term security of the journal. A great deal has been achieved towards satisfying those goals.

Five issues of The Canadian Field-Naturalist were published in 2012 (125(2) through to 126(2)), with a sixth issue, 126(3) being virtually ready to go by the end of the year. This gratifying rate of production is a credit to Carolyn Callaghan and her production team and has largely eliminated the lag in the publication schedule that we have been battling aggressively. This more current status is also positively reflected by a 20% increase in submitted manuscripts in 2012, by papers with increasingly contemporary subject matter, and by the reduced time span between the receipt and approval of manuscripts. The more frequent use of colour images continues to enhance the appearance of journal contributions.

A clearer understanding of the impact of digital publication on circulation patterns is emerging. A substantial majority of individual and institutional subscribers, 70% of the 460 subscribers, paid the additional cost to receive hard copies of The Canadian Field-Naturalist in 2012. Approximately 15% of the 700 OFNC members chose to do likewise, a large majority apparently satisfied to receive The Canadian Field-Naturalist in digital form only. While the financial benefits of digital publication are still difficult to quantify as we continue to bring the publication back up to a regular schedule, improvements are evident. The allocation required to balance the 2012 operational deficit, for example, amounted to 24% of 2011-12 membership income. That is considerable less than the 40% of membership fee income traditionally (1972-2007)

allocated as Canadian Field-Naturalist income. And it is hugely less than the 78% of 2010-11 membership income allocated to balance Canadian Field-Naturalist costs that year. Even allowing for the greater number of issues published in 2010-11, it is clear that significant progress is being made in improving the financial balance of the journal.

Editor Karen McLachlan Hamilton and her team produced the usual four issues of Trail & Landscape in a timely and efficiently manner this year. This constitutes another in their continuing series of remarkably problem free contributions to both our knowledge of the local landscape and to our enjoyment of it. An initiative to scan and post the back issues of Trail & Landscape on-line was begun in 2012.

The publications team enters 2013 with optimism gained from the successes of the past year. Both editorial teams are intact and stable. The Canadian Field-Naturalist will be completely back on schedule in the coming year. Financial benefits should be even clearer. Journal Manager Jay Fitzsimmons has done a masterful job ensuring that the complicated gears of The Canadian Field-Naturalist production and distribution machinery are turning smoothly. We also expect to be announcing firm ideas for a Canadian Field Naturalist endowment fund and perhaps news of up-coming Special Issues.

We encourage members and subscribers to continue to support the OFNC's remarkable publications program into its 134th year. Individuals can do this through their readership of the publications and, very importantly, through the submission of original material. Our thanks to all those who contributed to the success of this past year.

DANIEL F. BRUNTON, Chair



Canadian Field-Naturalist Editor in Chief Carolyn Callaghan (pointing), Journal Business Manager Jay Fitzsimmons (with his son Reed) and other members and friends of the Publications Committee afield in west Quebec (October 2012).

Treasurer

I assumed the duty of Treasurer at the January, 2012 Annual Business meeting. My predecessor, Frank Pope, provided and continues to provide invaluable advice and support. I would also like to thank Yi Zhang, who also greatly eased my learning curve as Treasurer's Assistant until June 2012. There were some new initiatives this year.

1. The desirability of obtaining Directors' and Officers' Insurance was investigated. Council decided to apply for this additional coverage for 2013. The cost is estimated at about \$660 plus tax.
2. The classification of revenues and expenses in our financial records has been reviewed in order to improve Council's ability to manage the financial affairs of the Club, and member's knowledge of Club finances. This is an ongoing task. For example,
 - a) Telephones used for the Bird Hotline and the Fletcher Wildlife Garden volunteers are now charged against the budgets of the Birds and FWG Committees;
 - b) Activities such as the Pelee trip whose revenues and expenses were previously reported on a net basis in the Operating Statement now show revenues and expenses separately.
3. Expense authorization procedures were adjusted to reflect the actual practices of the Club.

Most of the Treasurer's duties continue from one year to the next. They include:

- Filing the Charities Information Report with the Canada Revenue Agency;
- Preparing T4A returns for people receiving honoraria or contract fees from the Club;
- Obtaining Proof of Insurance certificates for Club events;
- Updating the Club's information with our bank, the Canadian Imperial Bank of Commerce, our investment advisor, BMO Burns Nesbitt, and our online payments processor, PayPal;
- Updating the Chart of Accounts; and
- Depositing cheques received and writing cheques to pay expenses.

Ultimately, the Treasurer is responsible for ensuring that the annual financial statements of the Club are available for the Annual Business Meeting. Fortunately, I did not have to do this by myself.

I would like to thank the President, Ann MacKenzie who ensured that our investments were correctly represented, and in general that the financial statements were coherent. Our reviewers, Mark Patry and Eric Liebmann of Welch LLP were very patient and thorough in their work. I sincerely thank Ann, Mark and Eric for easing the transition of a new Treasurer.

KEN YOUNG

Review Engagement Report

To The Members of THE OTTAWA FIELD-NATURALISTS' CLUB

We have reviewed the statements of financial position of the The Ottawa Field-Naturalists' Club as at September 30, 2012, September 30, 2011 and October 1, 2010, and the statements of operations, changes in fund balances and cash flows for the years ended September 30, 2012 and September 30, 2011. Our review was made in accordance with Canadian generally accepted standards for review engagements and accordingly consisted primarily of enquiry, analytical procedures and discussion related to information supplied to us by the club.

A review does not constitute an audit and consequently we do not express an audit opinion on these financial statements.

Based on our review, nothing has come to our attention that causes us to believe that these financial statements are not, in all material respects, in accordance with Canadian accounting standards for not-for-profit organizations.

CHARTERED ACCOUNTANTS
Licensed Public Accountants

Welch LLP

Ottawa, Ontario
December 17, 2012

The Ottawa Field-Naturalists' Club
Statement of Financial Position
September 30, 2012, September 30, 2011 and October 1, 2010

	Sept. 30, 2012	Sept. 30, 2011	Oct. 1, 2010
ASSETS			
CURRENT ASSETS			
Cash and cash equivalents (note 5)	\$ 156,201	\$ 201,906	\$ 78,103
Short-term investments (note 5)	43,817	—	98,954
Accounts receivable	16,138	33,482	2,388
Prepaid expenses	1,403	290	1,935
	<u>217,559</u>	<u>235,678</u>	<u>181,380</u>
Long-Term Investments (Note 5)	386,170	340,074	351,552
Land	—	—	3,348
	<u>\$ 603,729</u>	<u>\$ 575,752</u>	<u>\$ 536,280</u>
LIABILITIES AND FUND BALANCES			
CURRENT LIABILITIES			
Accounts payable and accrued liabilities	\$ 2,283	\$ 13,611	\$ 4,478
Deferred revenue	21,239	13,721	10,438
	<u>23,522</u>	<u>27,332</u>	<u>14,916</u>
LIFE MEMBERSHIPS (note 6)	1,240	3,360	5,480
FUND BALANCES			
General fund	303,378	272,458	276,297
Endowment fund	35,900	35,268	—
Internally restricted funds	239,689	237,334	239,587
	<u>578,967</u>	<u>545,060</u>	<u>515,884</u>
	<u>\$ 603,729</u>	<u>\$ 575,752</u>	<u>\$ 536,280</u>

Approved by Council:

..... President

..... Treasurer

(See accompanying notes)
PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club
Statement Of Operations and Changes in Fund Balance
– General Fund
Years Ended September 30, 2012 And 2011

	2012	2011
REVENUES		
Membership fees	\$ 30,308	\$ 32,412
Donations and bequests	21,954	18,190
The Canadian Field–Naturalist		
– subscription revenue	32,463	25,291
– author charges	27,984	44,040
Fletcher Wildlife Garden	5,684	5,055
Interest income	12,465	8,572
Peele Trip	14,375	–
Other	680	1,370
	<u>145,913</u>	<u>134,930</u>
EXPENSES		
OPERATING:		
Affiliation fees	225	225
Bookkeeping	6,525	7,353
Courier and postage	319	1,083
Insurance	782	580
Interest and bank charges	1,471	652
Membership	1,347	1,286
Professional fees	2,000	2,000
Website	710	3,300
General and miscellaneous	2,697	6,859
	<u>16,076</u>	<u>23,338</u>
ACTIVITY:		
The Canadian Field–Naturalist	52,758	92,868
Fletcher Wildlife Garden	19,012	9,945
Awards committee	372	858
Soiree – net	(184)	–
Birds Committee	971	739
Donations	5,000	3,348
Education and publicity	381	328
Excursions and lectures	1,445	115
Macoun Club	555	–
Peele Trip	11,049	–
Trail and Landscape	7,558	7,230
	<u>98,917</u>	<u>115,431</u>
TOTAL EXPENSES	<u>114,993</u>	<u>138,769</u>
NET REVENUES (EXPENSES)	<u>30,920</u>	<u>(3,839)</u>
FUND BALANCE,		
BEGINNING OF YEAR	<u>272,458</u>	<u>276,297</u>
FUND BALANCE,		
END OF YEAR	<u>\$303,378</u>	<u>\$272,458</u>

The Ottawa Field-Naturalists' Club
Statement of Operations and Changes in Fund Balance –
Endowment Fund
Years Ended September 30, 2012 and 2011

	2012	2011
Revenues		
Interest	\$ 1,263	\$ 535
Fund Balance, Beginning of Year	<u>35,268</u>	<u>–</u>
	36,531	535
Other		
Endowment contribution	–	35,000
Inter-fund transfer	(631)	(267)
Fund Balance, End of Year	<u>\$ 35,900</u>	<u>\$ 35,268</u>

* half of the interest generated by the fund annually is transferred to the Macoun Fund (see statement of operations and changes in fund balances – internally restricted funds).

* the prior years closing fund balance has been reduced from \$36,989 to \$35,268 to derecognize unrealized gains of \$1,721 previously recorded under CGAAP (note 2).

The Ottawa Field-Naturalists' Club
Statement of Cash Flows
Years Ended September 30, 2012 and 2011

	2012	2011
Cash Flows from Operating Activities		
Net revenues (expenses) – all funds	\$ 33,907	\$ (5,824)
Adjustments for:		
Accounts receivable	17,345	(31,094)
Investments	(15,956)	(8,340)
Prepaid expenses	(1,113)	1,645
Accounts payable and accrued liabilities	(11,329)	9,133
Deferred revenues	7,518	3,283
Life memberships	(2,120)	(2,120)
	<u>28,252</u>	<u>(33,317)</u>
Cash Flows from Investing Activities		
Purchase of investments	(120,000)	(25,000)
Proceeds from maturity of investments	<u>46,043</u>	<u>147,120</u>
	<u>(73,957)</u>	<u>122,120</u>
Cash Flows from Financing Activities		
Endowment contribution	–	35,000
Increase (Decrease) in Cash and Cash Equivalents	<u>(45,705)</u>	<u>123,803</u>
Cash and Cash Equivalents at Beginning of Year	<u>201,906</u>	<u>78,103</u>
Cash and Cash Equivalents at End of Year	<u>\$156,201</u>	<u>\$ 201,906</u>

Note: Cash equivalents include fixed income investments maturing within three months

(See accompanying notes)

PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club
Statement of Operations and Changes in Fund Balances – Internally Restricted Funds
Years Ended September 30, 2012 And 2011

	General Reserve for Contingencies	Manning Fund	Seedathon Fund	Anne Hanes Memorial Fund	De Kiriline Lawrence Fund	Macoun Fund	2012 Total	2011 Total
Revenues								
Donations	—	—	\$ 1,500	—	—	\$ 2,000	\$ 3,500	\$ 1,252
Interest	—	5,532	—	—	—	—	5,532	2,166
	—	5,532	1,500	—	—	2,000	9,032	3,418
Expenses								
CFN author support	—	6,051	—	—	—	—	6,051	4,147
Donations	—	—	—	—	—	313	313	1,035
Seed	—	—	944	—	—	—	944	722
Other	—	—	—	—	—	—	—	34
	—	6,051	944	—	—	313	7,308	5,938
Net Revenues (Expenses)	—	(519)	556	—	—	1,687	1,724	(2,520)
Fund Balances, Beginning of Year	100,000	120,322	232	596	13,384	2,800	237,334	239,587
	100,000	119,803	788	596	13,384	4,487	239,058	237,067
Other								
Inter-fund transfer	—	—	—	—	—	631	631	267
Fund Balances, End of Year	\$100,000	\$119,803	* \$788	\$596	\$13,384	\$5,118	\$239,689	\$237,334

* includes principal of \$100,000 plus undistributed income of \$19,803

The Ottawa Field-Naturalists' Club
Notes to the Financial Statements
Year Ended September 30, 2012 and 2011

1. Purpose of Organization and Tax Status

The Canadian Field-Naturalists' Club (the "Club") is a registered charitable organization incorporated under the Corporations Act of the Province of Ontario. The Club promotes the appreciation, preservation, and conservation of Canada's natural heritage, encourages the investigation, publishes the results of research in all fields of natural history, and diffuses the information to the public and supports and cooperates with other organizations engaged in preserving, maintaining and restoring environments of high quality for living things.

The Club is a registered charity, and is exempt from income taxes by virtue of section 149(1)(f) of the Income Tax Act (Canada).

2. Adoption of Accounting Standards for Not-for-profit Organizations

These financial statements are prepared in accordance with Canadian accounting standards for not-for-profit organizations (ASNFPPO).

These are the club's first set of financial statements prepared in accordance with ASNFPPO. The club previously presented financial statements under Canadian generally accepted accounting principles (CGAAP) annually to September 30 of each fiscal year up to, and including September 30, 2011.

As these financial statements are the first financial statements for which the club has applied ASNFPPO, the financial statements have been prepared in accordance with the provisions set out in Section 1501 *first-time adoption by not-for-profit organizations*. Accordingly, the club has applied ASNFPPO retroactively to all comparative financial statements presented and included an opening statement of financial position at October 1, 2010 (the date of transition).

Section 1501 provides organizations with certain elective exemptions to the principle that an organization's opening statement of financial position shall comply with ASNFPPO. The club has not elected to use any of the available exemptions.

The adoption of ASNFPPO results in adjustments to the previously reported assets, liabilities and fund balances of the club. The effect of adopting ASNFPPO retroactively to the opening statement of financial position as at October 1, 2010 (the date of transition) is as follows:

		CGAAP	Transition	ASNFPPO
Assets				
Investments	(a)	\$ 462,080	\$ (11,574)	\$ 450,506
Other assets		85,774	—	85,774
		<u>\$ 547,854</u>	<u>\$ (11,574)</u>	<u>\$ 536,280</u>
Liabilities and fund balances				
Current liabilities		\$ 14,916	\$ —	\$ 14,916
Life memberships		5,480	—	5,480
General fund	(b)	280,770	(4,473)	276,297
Internally restricted funds	(c)	246,688	(7,101)	239,587
		<u>\$ 547,854</u>	<u>\$ (11,574)</u>	<u>\$ 536,280</u>

2. Adoption of Accounting Standards for Not-for-profit Organizations— Cont'd.

(a) Under the requirements of Section 3856, <i>Financial Instruments</i> , the club will subsequently measure its investments at amortized cost unless the investments are an equity instrument that is quoted in an active market or a qualified derivative contract. Previously, the club was prohibited from recording its fixed income securities at amortized cost and had designated them as available-for-sale assets (fair value measurement). Unrealized gains and losses due to changes in fair value were previously recognized in the changes of financial position.	(b) General fund as at October 1, 2010, previously	\$ 280,770
	Adjustment for investments (a)	<u>(4,473)</u>
	General fund as at October 1, 2010 under ASNFPPO	<u>\$ 276,297</u>
	(c) Internally restricted funds as at October 1, 2010, previously	\$ 246,688
	Adjustment for investments (a)	<u>(7,101)</u>
	Internally restricted funds as at October 1, 2010 under ASNFPPO	<u>\$ 239,587</u>

The adjustment to the internally restricted funds affected the Manning Fund only. There were no adjustments required to any of the other internally restricted funds due to the above changes.

There were no changes to the organization's previously reported statement of operations or cash flows from operating, investing or financing activities as a result of the above changes.

3. Significant Accounting Policies

Basis of accounting

These financial statements have been prepared in accordance with Canadian accounting standards for not-for-profit organizations.

Revenue recognition

The club records revenue in accordance with the deferral method of accounting.

Membership fees are recorded as revenue in the general fund proportionately over the fiscal year to which they relate. The club's membership year coincides with the calendar year, so a proportionate share of the membership fees received are deferred until the end of the calendar year to which they relate.

Subscription revenue is recorded as revenue in the general fund at the time of shipment of the related publication. Subscription revenue received in advance of shipment is recorded as deferred subscription revenue.

Unrestricted contributions are recorded as revenue in the general fund when they are received. Restricted contributions are recognized as revenue in the year in which the related expenses are incurred. Endowment contributions are recognized as direct increases in fund balances.

Interest income comprises of interest from cash and cash equivalents and investments. Interest on cash equivalents and investments is recognized over their term using the effective interest method.

Fund accounting

The Club maintains its accounts in accordance with the principles of fund accounting. Resources are classified for accounting and reporting purposes into funds according to the activity or object specified.

The General Fund accounts for the Club's program delivery and administration activities.

The Endowment Fund was established by the family and friends of Martha Camfield to help continue her efforts to have children study, understand, respect and preserve their natural environment. Half of the interest generated is re-invested in the capital of the fund while the other half of the interest generated is made available only for the use by the Macoun Field Club (the Macoun Fund).

The General Reserve For Contingencies was established by the Club to fund outstanding operating expenses should the Club discontinue its operations.

The Manning fund was established by a bequest, and the interest generated is used to assist authors to publish articles in the Canadian Field Naturalist.

The Seedathon fund collects donations from the annual bird sighting event and purchases seed for the Club's bird feeders.

The Anne Hanes Memorial fund was raised in memory of Anne Hanes, the founding editor of Trail and Landscape, and is used to finance the annual winners of the Anne Hanes Natural History Award.

The de Kiriline-Lawrence fund was funded by a bequest from the popular author of nature books, and is supplemented by annual donations and used to support conservation efforts.

The Macoun Baille Birdathon fund recognizes the donations and pledges based upon the number of bird sightings in the one day birdathon sponsored by Bird Studies Canada, and is used to support the Macoun Field Club, a youth club.

Financial Instruments

The club's cash is measured at fair value. All other financial instruments are measured at amortized cost.

Cash and cash equivalents

Cash and cash equivalents consist of cash on hand and highly liquid investments. Cash equivalents consist of fixed income investments maturing within three months.

Capital assets

Capital assets are expensed in the year of acquisition.

Contributed services

The Club relies on contributed human resources in order to carry out its activities. As there is difficulty in determining the fair value of contributed services, they are not recognized in the financial statements.

Use of estimates

The preparation of financial statements in conformity with Canadian accounting standards for not-for-profit organizations requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from these estimates.

4. Financial Instruments

The club's financial instruments are subject to the following risks:

a) *Credit risk*

The club is exposed to credit risk resulting from the possibility that parties may default on their financial obligations, or if there is a concentration of transactions carried out with the same party, or if there is a concentration of financial obligations which have similar economic characteristics, that could be similarly affected by changes in economic conditions, such that the club could incur a financial loss. The club does not hold directly any collateral as security for financial obligations of counterparties.

The club's maximum exposure to credit risk represents the carrying value of its cash, accounts receivable and investments, totalling \$602,326 (2011 – \$575,462).

The club's cash is deposited with Canadian financial institutions, as a result management believes the risk of loss on cash to be remote. The cash equivalents and investments consist primarily of government bonds and guaranteed investment certificates of Canadian financial institutions of high credit quality. Possible changes to the credit quality of these securities exposes the club to credit risk. The club manages its exposure to this risk by holding a diversified portfolio with varied maturities. The club reduces its exposure to credit

risk on its accounts receivable by reviewing the accounts on a regular basis, following up on outstanding amounts and creating an allowance for doubtful accounts when applicable.

No allowance for impairment has been recorded on any of the items subject to credit risk.

b) *Liquidity risk*

Liquidity risk is the risk that the club cannot meet its debts when they become due. Liquidity risk also includes the risk of the club not being able to liquidate assets in a timely manner at a reasonable price.

The club meets its liquidity requirements by monitoring its expected future cash flow requirements and holding a significant amount of assets that can be readily converted into cash.

c) *Market risk*

Market risk is the risk that fair value or future cash flows of a financial instrument will fluctuate because of changes in market prices. Market risk is comprised of currency risk, interest rate risk and other price risk.

d) *Currency risk*

Currency risk refers to the risk that the fair value of financial instruments or future cash flows associated with the instruments will fluctuate relative to the Canadian dollar due to changes in foreign exchange rates.

Approximately \$14,000 (2011 – \$5,000) of club's cash and cash equivalents are denominated in U.S. currency. However, the club primarily transacts in Canadian dol-

lars. As a result, management does not believe it is exposed to significant currency risk.

e) *Interest rate risk*

Interest rate risk refers to the risk that the fair value of financial instruments or future cash flows associated with those instruments will fluctuate due to changes in market interest rates. The exposure of the club to interest rate risk arises from its interest bearing assets.

The club's cash includes amounts on deposit with Canadian financial institutions that earn interest at market rates. Fluctuations in market rates of interest on cash do not have a significant impact on the club's financial operations.

The club manages the interest rate risk of its cash equivalents and investments by using a ladder portfolio with varying terms to maturity. The ladder structure of maturities helps to enhance the average portfolio yield while reducing the sensitivity of the portfolio to the impact of interest rate fluctuations.

f) *Other price risk*

Other price risk refers to the risk that the fair value of financial instruments or future cash flows associated with the instruments will fluctuate because of changes in market prices (other than those arising from currency risk or interest rate risk), whether those changes are caused by factors specific to the individual instrument or its issuer or factors affecting all similar instruments traded in the market.

The club is not exposed to other price risk.

5. Investments And Cash Equivalents

Cash equivalents are comprised of:

	2012		2011
	Market Value	Amortized Cost	Amortized Cost
Cash in accounts – at fair value	\$ 88,792	\$ 88,793	\$ 136,624
Canadian Western Bank – 4.41% due October 9, 2012	30,870	30,872	–
CIBC GIC – 1.4% due October 12, 2012	21,284	21,284	–
Ontario – 4.64% due December 2, 2012	15,346	15,252	–
Newfoundland – 4.58% due October 17, 2011	–	–	44,548
CIBC GIC – 1.4% due October 3, 2011	–	–	20,734
	<u>\$ 156,292</u>	<u>\$ 156,201</u>	<u>\$ 201,906</u>

Short-term investments are comprised of:

	2012		2011
	Market Value	Amortized Cost	Amortized Cost
Manitoba – 4.75% due September 2, 2013	\$ 45,235	\$ 43,817	\$ –

Long-term investments are comprised of:

	2012		2011
	Market Value	Amortized Cost	Amortized Cost
Canadian Western Bank – 4.41% due October 9, 2012	\$ –	\$ –	\$ 28,344
Ontario – 4.64% due December 2, 2012	–	–	14,575
Manitoba – 4.75% due September 2, 2013	–	–	41,830
CIBC – 4.19% due October 31, 2014	67,827	65,056	62,440
New Brunswick – 4.30% due December 3, 2015	65,003	60,850	61,117
Ontario Hydro – 4.01% due November 26, 2016	23,160	25,054	24,088
Ontario – 4.07% due December 2, 2017	51,572	46,687	44,861
Ontario – 2.58% due December 2, 2018	62,398	61,280	–
British Columbia – 3.74% due March 5, 2019	29,021	26,491	25,536
Newfoundland – 4.36% due January 7, 2020	43,771	38,908	37,283
British Columbia – 3.26% due August 23, 2021	63,945	61,844	–
	<u>\$ 406,697</u>	<u>\$ 386,170</u>	<u>\$ 340,074</u>

6. Commitments

Rent

The Club is committed to rent a room at the Canadian Museum of Nature which the club intends to use to conduct monthly meetings until June 2013. The cost is expected to be for \$200 per month plus applicable sales taxes. The room is not scheduled to be rented in the month of January 2013.

Life memberships

The Club is committed to provide for regular membership benefits to lifetime members. Since it is not practicable to determine the total liability associated with providing these benefits for the rest of the lives of these individuals, the annual costs are expensed as incurred. Lifetime memberships are no longer being offered by the Club. As of September 30, 2012, there were 51 (2011 – 53) active lifetime members.

Fletcher Wildlife Garden

The Club is committed to maintaining a 13-acre property known as the Fletcher Wildlife Garden until March 31, 2014. The costs associated with maintaining the property are approximately 2,000 hours of contributed human resources per year. As the fair value of contributed human resources are not recognized in the financial statements, the corresponding costs are also not recognized as part of the Fletcher Wildlife Garden expenses in the statement of operations of the General Fund. The Club incurs those expenses over and above the Club's service requirements under the agreement.

7. COMPARATIVE FIGURES

Certain comparative figures have been reclassified where necessary to conform to the presentation adopted in the current year. The October 1, 2010 figures were reviewed by another accountant.

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The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency the Right Honourable David Johnston, C.C., C.M.M., C.O.M., C.M.
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

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The Canadian Field-Naturalist

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COVER: Canada lynx (*Lynx canadensis*) in the sub-boreal forest of central British Columbia, December 2004. Photo: D. Hodder.
See pages 310–318 in this issue.

Density and Abundance of the Freshwater Pearl Mussel, *Margaritifera margaritifera*, in the Kennebecasis River, New Brunswick and Evidence of Recent Recruitment

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Freshwater Pearl Mussel, *Margaritifera margaritifera* (L., 1758) populations are endangered or threatened throughout Europe, and those in eastern Canada are believed to be some of the most abundant populations remaining worldwide. Although *M. margaritifera* occurs widely in Atlantic Canada, there is little information to allow its conservation status in the region to be assessed or to place these populations in a global context. Using 0.25 m² survey quadrats, maximum densities of *M. margaritifera* in six mussel beds on the Kennebecasis River and a tributary in southeastern New Brunswick were found to range from 12 to 200 m⁻². Mean densities at the five mainstem sites ranged from 1.9 m⁻² (SE±0.4) to 16.0 m⁻² (±4.3). Mean density on the tributary stream was 1.2 m⁻² (SE±0.7). Abundance of *M. margaritifera* at the six sites ranged from 4,536 (SE±2,600) to 55,520 (SE±14,768) and together the six mussel beds supported an estimated 161,315 Freshwater Pearl Mussels. The presence of juvenile *M. margaritifera* as small as 11.5 mm at the most upstream site, and Freshwater Pearl Mussels <30 mm at all sites, indicates that there had been recruitment of *M. margaritifera* juveniles in the Kennebecasis River in the 4–6 years prior to the 2007–2008 study.

Key Words: *Margaritifera margaritifera*; Freshwater Pearl Mussel; Eastern Pearlshell; freshwater mussels; conservation; density; abundance; Kennebecasis River; recruitment; New Brunswick; Canada

The Freshwater Pearl Mussel, *Margaritifera margaritifera* (also known as the Eastern Pearlshell), is one of 10 extant species of freshwater mussels that occur in New Brunswick (Martel et al. 2010). The species is holarctic in distribution (Bauer 1997) but has been extirpated from much of Europe, where it was previously abundant (Young and Williams 1983). Elsewhere, although adults remain plentiful in some regions, populations are declining. The Freshwater Pearl Mussel is now considered among the most endangered of aquatic organisms worldwide (Beasley et al. 1998; Strayer et al. 2004; Araujo et al. 2009; Thomas et al. 2010). *Margaritifera margaritifera* populations in the United States are vulnerable, imperiled, critically imperiled, or in need of assessment (Strayer and Jirka 1997; Young et al. 2001). While Canadian *M. margaritifera* populations appear to be secure, the species is in need of conservation assessment in Canada. Although juvenile *M. margaritifera* (<50 mm) have been reported in the Petitcodiac River, New Brunswick (Hanson and Locke (2001) and in the Rivière du Gouffre, Quebec (Martel and McAlpine 2007), demonstration of recent recruitment into Canadian populations of this exceedingly

long-lived, salmonid-dependant, species are generally lacking (Martel et al. 2010).

Explanations offered for the decline of *M. margaritifera*, and Unionacea more broadly, include past commercial and current illegal harvest for pearls, loss of host fish species, habitat alteration, and pollution (Young et al. 2001; Strayer et al. 2004; Geist 2010; Hastie et al. 2010). Climate change may prove to be a serious threat to the Freshwater Pearl Mussel in the near future, dependant as it is on coldwater fish hosts (Hastie et al. 2003). In North America, Atlantic Salmon (*Salmo salar*) is believed to be the main host species. However, other salmonids, including Brook Trout (*Salvelinus fontinalis*), Brown Trout (*Salmo trutta*) and Arctic Charr (*Salvelinus alpinus*) are also reported to serve as hosts (Smith 1976; Thomas et al. 2010; Thomas 2011), although North American evidence for such is limited (Smith 1976; Martel et al. 2010).

Accounts from the late 19th C of freshwater pearls collected from the Saint John River basin (Ganong 1889) indicate *M. margaritifera* populations in the region are long standing, and eastern Canadian populations of the species may represent some of the largest

remaining stocks (Martel and McAlpine 2007). Nonetheless, the study reported here appears to be the first to estimate density in a Canadian *M. margaritifera* population using standardized survey methods for freshwater mussels (Strayer and Smith 2003).

Our objectives were to characterize a sample of mussel beds (area, water depth, flow, substrate, associated species) supporting *M. margaritifera* within the Kennebecasis River system; to determine the density and abundance of *M. margaritifera* in these beds; to determine whether density varied among sites; and to assess whether recent recruitment of *M. margaritifera* has taken place in this population. This information will provide the basis for any future conservation monitoring of *M. margaritifera* in the Kennebecasis River.

Methods

Selection of study sites

The Kennebecasis River is located within the Saint John River basin in southeastern New Brunswick. It is a 5th order river that includes nine 4th order tributaries. The river drains a basin of 1,110 km² (Hansen and Bray 1993) and flows approximately 103 km from Hamilton Lake to where it enters the Saint John River at Boars

Head, west of Saint John (Figure 1). The head of freshwater tidal influence is at Bloomfield, Kings County. The Kennebecasis is not impounded, with most of the river flowing over a late Devonianearly Carboniferous sedimentary basin (Miller and Brazeau 2007; St. Peter and Johnson 2009).

Six study sites occupying the mid-reaches of the river from Penobsquis (most upstream) to above Bloomfield (most downstream) were selected based on a search of New Brunswick Museum specimen records and site visits to assess the presence of *M. margaritifera* (Figure 1, Table 1). With the exception of a few small beds of *M. margaritifera* 1–2 km upstream of Penobsquis, searches of >20 km of river channel upstream of Penobsquis to above Portage Vale revealed no additional mussel beds. However, we observed numerous mussel beds between Penobsquis and Sussex that we did not survey.

The river course spanning our study sites passes through agricultural lands (primarily pasture), although a narrow wooded riparian zone borders much of the river, particularly in its upper mid-reaches (Figure 2). Mussel beds were delineated by three people snorkeling the width of the stream in a diagonal, criss-cross pattern, working downstream. The boundaries of any

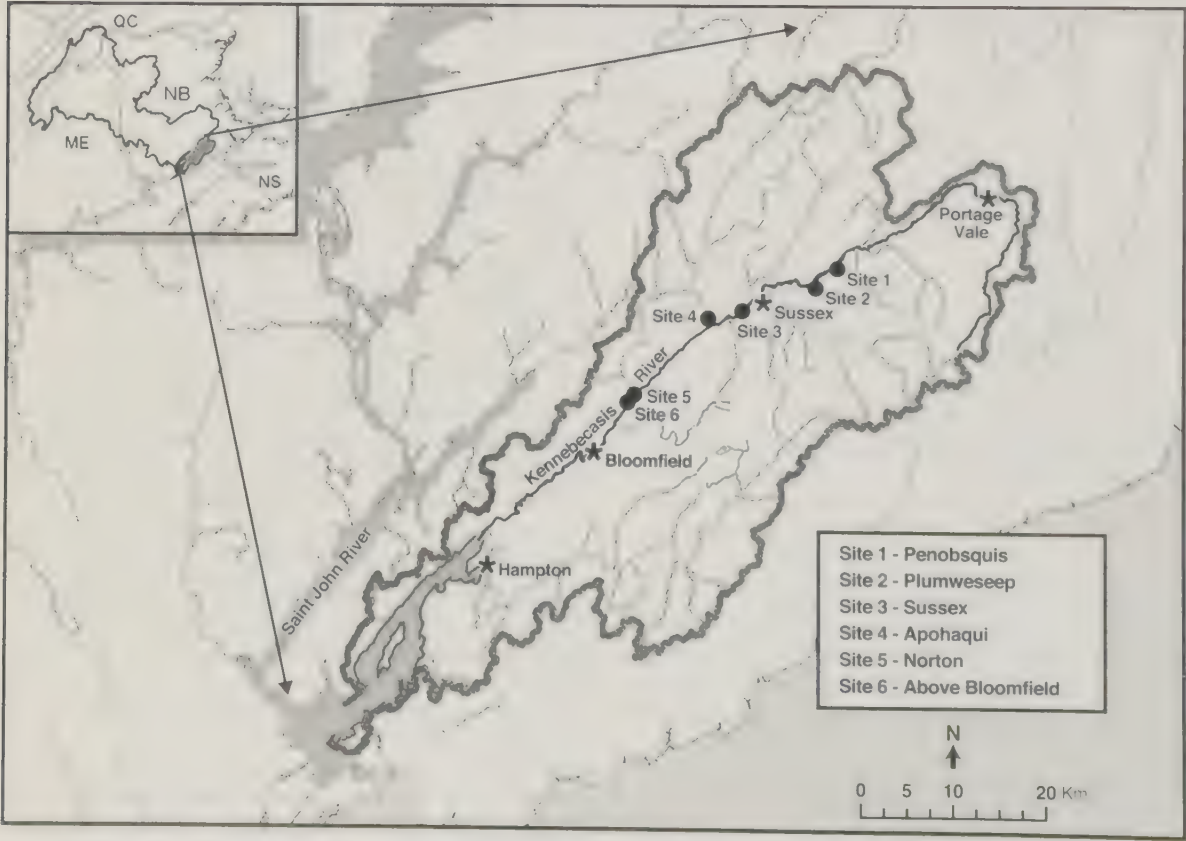


FIGURE 1. Map of the Kennebecasis River within the Saint John River basin (latter outlined in the inset map), New Brunswick, showing sites of *Margaritifera margaritifera* (Freshwater Pearl Mussel) sampling in 2007 and 2008. The Kennebecasis River drainage is outlined.

TABLE 1. *Margaritifera margaritifera* (Freshwater Pearl Mussel) beds at study sites on the Kennebecasis River, New Brunswick in 2007 and 2008. Sites are arranged from most upstream (top) to most downstream (bottom). Site numbers are marked on Figure 1. Length of bed given is the maximum, width is the mean of four measures. Bed areas at Plumweseep and Above Bloomfield bed have been adjusted by subtracting areas of exposed vegetated islands that divided the bed. Bed areas are rounded to 3 significant figures.

Site	Latitude	Longitude	Length (m)	Width (m)	Area (m ²)	Mean water depth (m)	Mean Water velocity (m·s ⁻²)	Predominate substrate
Penobsquis	45.76461	-65.42220	169	15.3	2590	0.68	ND	cobble
Plumweseep	45.74147	-65.44705	200	17.8	3470	0.53	0.08	gravel
Sussex	45.72103	-65.54570	134	25.5	3420	0.50	0.28	cobble
Apohaqui*	45.70444	-65.59921	200	18.9	3780	0.28	0.10	sand/cobble
Norton	45.63615	-65.70009	150	37.9	5690	0.72	ND	cobble
Above Bloomfield	45.62853	-65.71112	200	42.3	6270	0.65	0.20	cobble

*On the Millstream River, a tributary of the Kennebecasis River



FIGURE 2. Most upstream (A: Penobsquis; 2007) and most downstream (B: Above Bloomfield; 2008) *Margaritifera margaritifera* (Freshwater Pearl Mussel) study sites on the Kennebecasis River, New Brunswick. Note the lack of forested riparian cover at the Above Bloomfield site. Photos: M. Sollows/NB Museum.

mussel bed located were considered to be 10 m beyond the first upstream and last downstream *M. margaritifera* sighted. Ten metres was chosen as a cut-off to allow for small gaps containing no mussels within a bed and follows the protocol used by Baird (2000) during study of the margaritiferid *Cumberlandia monodonta* (Spectaclecase).

Three mussel beds (Penobsquis, Sussex and Norton) were sampled from May to September 2007 and three beds (Plumweseep, Apohaqui and Above Bloomfield) were sampled from June to September 2008. Five of the sites were located on the mainstem of the Kennebecasis River, while the Apohaqui bed was located on the Millstream River, a tributary of the Kennebecasis.

Mussel bed characteristics

Individual beds were characterized on the basis of area (maximum length × width at 30 m intervals along the bed length, minus any exposed vegetated islands that divided the bed), mean water depth taken at the mid-point of 60 0.25 m² sampling quadrats (*n* = 60 samples for each bed), and mean water velocity taken at three points through the water column with a digital flowmeter (Model 6597 Flowatch flow meter, JDC Electronics SA, Waadt, Switzerland) at the mid-point

of each quadrat from ~5 cm above the substrate vertically to the surface (*n* = 180 samples for each bed). The predominant substrate type for 105 of the 169 quadrats that contained *M. margaritifera* was visually characterized as silt (<0.5 mm), sand (0.5–2 mm), gravel (2–4 mm), cobble (64–256 mm), or boulder (>256 mm). Substrates >4 mm and <64 mm were not present in quadrats occupied by *M. margaritifera*.

Sampling for Freshwater Pearl Mussels

Mussel beds were sampled using 0.25 m² quadrats, the recommended standard for surveys of freshwater mussels (Strayer and Smith 2003; Pooler and Smith 2005). Sixty randomly placed 0.25 m² quadrats (95% confidence interval with a desired precision of 30%) were searched at each of six beds (*N* = 360) to estimate the mean number of individuals in each mussel bed. The 30% precision rate was chosen as an intermediate level between the 25% precision that Dunn (2000) recommended for large rivers and the 50% precision she recommended for small streams.

Quadrats were surveyed for mussels by snorkeling (where water depth was <1 m) or by SCUBA (depths >1 m). Mussels visible at the substrate surface were removed from each quadrat and placed in a mesh bag.

The entire quadrat was then excavated on the bottom by hand or with a metal scoop to a depth of 15 cm, and the substrate sorted through a quadrat-sieve fitted with 5 mm diameter screen (McAlpine and Sollows *in press*). Additional hand-held sieves (screen size 5 mm diameter) were also used where water velocity was low.

We followed Hastie and Cosgrove (2002) and accepted the presence of *M. margaritifera* <30 mm in length as evidence of recent juvenile recruitment and we used the approach of Hendelberg (1961) to estimate the age of juvenile mussels. Hendelberg (1961) reports that external annuli on the untreated surface (i.e. periostracum intact) of *M. margaritifera* shells can be counted (one increment = 1 year) and used to age mussels up to 15 years.

Statistical analyses

All data were examined for normality and equality of variance. The density of occurrence of Freshwater Pearl Mussels among sites was tested by non-parametric Kruskal-Wallis since the data were not normally distributed. Densities and abundances are reported as the mean and standard error of the mean (SE). Analyses were carried out using SYSTAT 11.0 (Systat Software, Inc., Chicago, Illinois).

Results

Mussel bed characteristics

The six mussel beds ranged from 2590 to 6270 m² and extended over as much as 200 m of the length of the stream channel. Mean water depth over beds during the sampling period ranged from 0.28 to 0.72 m and mean water velocity from 0.08 to 0.28 m · s⁻¹ (Table 1). Quadrats in which *M. margaritifera* were present were dominated by cobble (Pearson χ^2 = 82.092, df = 25, *P* < 0.001), but *M. margaritifera* also occurred commonly on gravel and sand substrates; *M. margaritifera* were least common in quadrats dominated by silt or boulders. At three of the study sites (Apohaqui, Norton and Above

Bloomfield) four additional mussel species were found in association with *M. margaritifera*; *Alasmidonta undulata*, *Anodonta implicata*, *Elliptio complanata*, and *Pyganodon cataracta*.

Density and abundance

Overall, 650 *M. margaritifera* were found on the Kennebecasis mainstem and Millstream River tributary, with 46.9% (*n* = 169) of quadrats occupied by Freshwater Pearl Mussels. However, the percentage of quadrats occupied by *M. margaritifera* among sites was highly variable, ranging from 13.3% at Apohaqui to 60.0 % at Norton (Table 2). As expected, *M. margaritifera* were not evenly distributed across beds but were clumped, with maximum densities ranging from 12 to 200m⁻² (Table 2). Mean density of *M. margaritifera* was highest at Plumweseep (16.0 m⁻² (SE±4.3)) and lowest at Apohaqui (1.2 m⁻² (SE±0.7)), the tributary site.

There was no difference in the average density of *M. margaritifera* among beds at Penobsquis, Plumweseep, Sussex and Norton (*P* = 0.065, Kruskal-Wallis = 7.225, df = 3), the four most upstream mainstem sites. However, there were significant differences between sites when Above Bloomfield (*P* = 0.001, Kruskal-Wallis = 18.749, df = 4) or Above Bloomfield and Apohaqui, the most downstream mainstem and tributary sites respectively, were included (*P* = 0.001, Kruskal-Wallis = 20.888, df = 5). Our estimates of mean density suggest that the six mussel beds investigated on the Kennebecasis River system supported ~161,315 *M. margaritifera*, ranging from a low of 4,536 (SE±2,600) at Apohaqui to a high 55,520 (SE±14,768) at Plumweseep.

Recruitment

All live *M. margaritifera* <30 mm in length in the Kennebecasis River were found completely buried, demonstrating the necessity of excavation to establish recruitment. Evidence of recent recruitment of *M. margaritifera* was detected at all six study sites, with

TABLE 2. Summary of *Margaritifera margaritifera* (Freshwater Pearl Mussel) density (number m⁻²), estimated abundance, and associated data at sampling locations along the mid-reach of the Kennebecasis River, New Brunswick in 2007 and 2008. Sites are arranged from most upstream (left) to most downstream (right). Total number of *M. margaritifera* encountered in the 60 0.25 m² quadrats sampled at each mussel bed is shown as *n*. The percentage of quadrats occupied by *M. margaritifera* at each site is shown as Percentage of quadrats occupied. Densities of *M. margaritifera* are reported as the mean number across the 60 quadrats and standard error of the mean with the minimum, maximum, and median in parentheses. Abundance is the estimated total/bed with standard error of the mean. See Table 1 for total areas of individual mussel beds. *N* < 30 mm refers to the number of individual *M. margaritifera* < 30 mm total length in each bed and follows Hastie and Cosgrove (2002) as evidence of recent juvenile recruitment.

	Penobsquis (n=135)	Plumweseep (n=240)	Sussex (n=139)	Apohaqui* (n=18)	Norton (n=89)	Above Bloomfield (n=29)
% occupied	53.3	55.0	51.7	13.3	60.0	48.3
Density	9.0±1.7 (0,52,4)	16.0±4.3 (0,200,4)	9.3±2.0 (0,68,4)	1.2±0.7 (0,40,0)	6.0±0.9 (0,24,4)	1.9±0.4 (0,12,0)
Abundance	23,310±4,434	55,520±14,768	31,696±6,771	4,536±2,600	34,140±5,258	12,113±2,633
<i>N</i> < 30 mm	22	14	8	1	2	1

*On the Millstream River, a tributary of the Kennebecasis River

the smallest *M. margaritifera*, collected at Penobsquis, being 11.5 mm total length. External annuli on the shells of Kennebecasis River *M. margaritifera* of <30 mm shell length suggest these mussels are 4–6 years of age.

However, recruitment appeared to be uneven. The greatest number of *M. margaritifera* <30 mm total length across the 60 quadrats per site sampled were found at the most upstream study sites (Penobsquis, Plumweseep, Sussex; $n = 22, 14, 8$ respectively). Only 1 or 2 Freshwater Pearl Mussels <30 mm were collected at each of the other three sites downstream (Table 2).

Discussion

Study sites and mussel bed characteristics

Many North American rivers have been impounded and this has had a deleterious effect on numerous freshwater mussel populations and distributions and those of their fish hosts (Vaughn and Taylor 1999). The lack of impoundments on the Kennebecasis River has been important in ensuring the persistence of the *M. margaritifera* population on this river, even in the face of serious declines in Atlantic Salmon stocks in the Saint John River basin (Cunjack and Newbury 2005).

Mean water velocities recorded at mussel beds on the Kennebecasis River (0.08 to $0.28 \text{ m}\cdot\text{s}^{-1}$) were comparable to optimum current velocities reported for *M. margaritifera* habitat in Europe (0.25 – $0.75 \text{ m}\cdot\text{s}^{-1}$; Hastie *et al.* 2000b and references cited therein). The presence of *M. margaritifera* is often reported to be associated with low water depth (Gittings *et al.* 1998; Morales *et al.* 2004). However, the mean summer water depths over mussel beds in the Kennebecasis River (0.28 – 0.72 m) in 2007 and 2008 were lower than the optimum (0.3 – 0.4 m) computed from habitat suitability curves for this species (Hastie *et al.* 2000a), suggesting that drier summers could pose a threat to at least some of the *M. margaritifera* population in the Kennebecasis River. Hastie *et al.* (2003) identified changing weather patterns leading to prolonged dry periods as a threat to *Margaritifera* populations.

Many investigators report the preference of *M. margaritifera* for sandy, gravelly, or cobble bottoms (Nedeau *et al.* 2000; Martel *et al.* 2010) and Hastie *et al.* (2000a) found *M. margaritifera* density more closely related to characteristics of the substrate than other features. Although *M. margaritifera* on the Kennebecasis River occurred most frequently in quadrats dominated, in descending order, by cobble, gravel, or sand, and although Freshwater Pearl Mussels appeared to avoid areas of boulder bottom, there is evidence that mussel beds occur where sediments are relatively stable. Boulders in a watercourse may play an important role in providing this stability (Layzer and Madison 1995; Strayer 1999).

Geist and Auerswald (2007) found that stream beds in which the interstitial spaces of the substrate had become clogged with mud, and subsequently compact-

ed, were unsuitable for *M. margaritifera*. This emphasizes the importance of controlling sedimentation in the Kennebecasis River from upstream agricultural and forestry operations and the value of maintaining forested riparian zones.

Density

Maximum densities of *M. margaritifera* for each of the six beds in this study (12 to 200 m^{-2}) are within the range of 10 – 50 m^{-2} , categorized as high by Martel and McAlpine (2007), but much lower than historic densities reported by others. Densities of 400 m^{-2} are cited for Scottish streams in the mid-1980s and it is speculated that historic densities exceeded 1000 m^{-2} (Bauer 1987). Hanson and Locke (2001) surveyed freshwater mussel species at various sites on the Petitcodiac River (New Brunswick) and categorized *M. margaritifera* as “abundant” ($>1 \text{ mussel m}^{-2}$) at only 13% of 52 sites examined.

Mean densities of *M. margaritifera* have been reported to be highly variable among sites, even within a single river (Outeiro *et al.* 2008; Hastie *et al.* 2010). Hastie *et al.* (2004) considered mussel densities $>1 \text{ m}^{-2}$ as indicative of “optimal mussel habitat”. According to Young *et al.* (2003), densities of Freshwater Pearl Mussels $>10 \text{ m}^{-2}$ indicate conditions favorable for the viability of *M. margaritifera* beds (i.e. for producing juveniles). While this might suggest that only the Plumweseep bed of the six mussel beds studied is viable, the presence of *M. margaritifera* <30 mm at all sites suggests this is not the case. Mean densities of *M. margaritifera* in two Iberian streams ranged from 0.27 to 6.55 m^{-2} (Outeiro *et al.* 2008). Although these densities are relatively low compared to densities recorded in Scotland (1.8 – 37.4 m^{-2} ; Hastie *et al.* 2010) and Sweden (maximum $\sim 24 \text{ m}^{-2}$ Arvidsson *et al.* 2012), populations in the Spanish streams were judged to be viable. Given that the lowest mean density/bed recorded in the Kennebecasis River system was 1.2 m^{-2} (Apoahqui) and the mean density at most sites was much higher, density alone would suggest that the *M. margaritifera* population in the Kennebecasis River is viable.

Arvidsson *et al.* (2012) surveyed 107 streams in Sweden and estimated total population sizes of *M. margaritifera* of 50–290,000 in individual streams, with a mean abundance of 27,281/stream ($\text{SE} \pm 5,383$). While Arvidsson *et al.* (2012) found that mussel density was more important to recruitment than the density of host fish, population size in itself seems to be a poor predictor of recruitment in the Freshwater Pearl Mussel. Recruiting populations in Swedish streams had as few as 100 individuals and non-recruiting populations as many as 252,000 *M. margaritifera*. While it is not possible to provide an estimate of the total number of *M. margaritifera* in the entire Kennebecasis River, the estimate of $\sim 161,315$ for the six beds surveyed (extrapolated from the 15 m^2 sampled in each bed ($60 \times 0.25 \text{ m}^2$) to the entire bed) is well above the mean reported by Arvidsson *et al.* (2012) for Swedish streams.

Recruitment

Small *M. margaritifera* are notoriously difficult to find in the field (Young and Williams 1984; Hastie and Cosgrove 2002; Hastie *et al.* 2010) and individuals <10 mm, although present, may not be detected even with sieving (Hastie *et al.*, 2000a; Young *et al.*, 2001). Although Hastie *et al.* (2010) were able to detect *M. margaritifera* as small as 6 mm, Hastie and Cosgrove (2002) experimentally demonstrated a size-specific sampling bias towards Freshwater Pearl Mussels >50 mm. Hastie *et al.* (2010) found considerable within-river variation in recruitment levels among sites, findings that seem to agree with ours.

As Hanson and Locke (2001) have noted, populations of non-reproducing *M. margaritifera* can persist for decades in this exceedingly long-lived species. Although many eastern Canadian rivers appear to host sizable populations of *M. margaritifera*, there are few data confirming recent recruitment in these rivers. Arvidsson *et al.* (2012) defined recruiting *M. margaritifera* populations as those where at least one mussel <50 mm was found, implying that recruitment had occurred in the last 15–20 years. On this basis, our data provide ample evidence that recent recruitment has occurred at all six sites sampled on the Kennebecasis River.

In conclusion, the population of *M. margaritifera* in the Kennebecasis River shows evidence of recent recruitment and densities of the Freshwater Pearl Mussel suggest a viable population. However, ensuring the persistence of *M. margaritifera* in the river in the future will require continuing attention to streamside habitat so that host fish populations do not decline, sedimentation does not become a problem, and summer water temperatures do not increase. Considering that *M. margaritifera* is at risk globally, and the potential importance of eastern North American populations, determining the viability of the Freshwater Pearl Mussel in other salmonid river systems in eastern Canada should be a priority.

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Canada Lynx (*Lynx canadensis*) Detection and Behaviour Using Remote Cameras during the Breeding Season

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The efficacy of surveys in detecting Canada Lynx (*Lynx canadensis*) can vary considerably by geographic area. We conducted surveys using digital passive infrared trail video-cameras from January to April 2013, during the breeding season of the Canada Lynx, in the John Prince Research Forest in central British Columbia. We used snow-track surveys to test the efficacy of our camera surveys. We measured trail camera detection rates by survey week and location and we noted Canada Lynx activity and behaviours recorded by the cameras. The detection rate increased between January and April, reaching a peak of 8 Canada Lynx/100 camera-days in early April. Canada Lynx spent more time at camera sites displaying behaviours such as scent-marking and cheek-rubbing in late March. The combination of both snow-track and trail camera surveys was especially effective, with Canada Lynx detected at 77% of all monitored sites. Depending on survey objectives, it may be beneficial to conduct camera as well as other non-invasive survey methods for Canada Lynx during the breeding season, when survey efficacy and detection rates are maximized.

Key Words: British Columbia; behaviour; breeding season; Canada Lynx; *Lynx canadensis*; detection; non-invasive; trail cameras; snow-tracking survey; British Columbia

Introduction

Non-invasive field surveys are commonly used to assess and monitor the presence, distribution, and/or abundance of carnivores (e.g., Patterson *et al.* 2004; Squires *et al.* 2004; Rosatte 2011). These surveys are often used as the basis for management decisions and actions, such as setting harvest quotas and assigning conservation status. Effective and reliable methods of detecting individuals across a species' range are therefore needed to monitor populations and inform management decisions.

The efficacy of survey methods for Canada Lynx (*Lynx canadensis*) can vary considerably by geographic area (McDaniel *et al.* 2000; Crowley *et al.* 2005*; Burdett *et al.* 2006*; Moen and Lindquist 2006*; McKelvey *et al.* 2006; Squires *et al.* 2012), and there is currently no single survey technique that can be applied consistently and uniformly across its range. The animal's elusive nature, large spatial requirements, and dense forested habitat present several statistical and logistical challenges to the design of detection and abundance surveys. In addition, large fluctuations in populations through space and time may increase the variance in the number of Canada Lynx detected among survey plots and years and may change the effort needed for detection (Squires *et al.* 2012).

Trail cameras, hair snares, and snow-track surveys have all been used with mixed success to detect Canada Lynx. Hair snares have worked well in the northern boreal forest of southern Yukon and British Columbia

(McDaniel *et al.* 2000), but have not been very effective in other areas, such as Minnesota or Maine (Crowley *et al.* 2005*; Burdett *et al.* 2006*).

Snow-track surveys have proven to be an effective method of detecting Canada Lynx (Squires *et al.* 2004, 2012), but survey logistics and conditions can often make it difficult to take advantage of limited survey opportunities. This method depends on fresh snow from snowstorms, which may be infrequent; in addition, windy days, snow crusts, and melting snow can disrupt survey schedules or make it impossible to conduct snow-track surveys. Consequently, for snow tracking to be successful over large geographic areas, regular snow events and/or multiple survey crews are needed to take advantage of suitable tracking conditions. Another limitation of this technique is its reliance on the accurate reading of track sign by trained observers.

Snow tracking does not provide indisputable evidence of the presence of Canada Lynx, compared to DNA or photographic evidence. Track misidentification can be particularly problematic in areas where the ranges of the Canada Lynx and the Bobcat (*Lynx rufus*) overlap. Although combining snow tracking and DNA sampling for Canada Lynx has been successful in some areas (McKelvey *et al.* 2006), this approach requires more effort using methods that are already limited by suitable environmental conditions. Alternative or complementary field methods to snow-track surveys would be useful for the efficient and reliable monitoring of Canada Lynx populations.

Although trail cameras are frequently used as a detection technique for many felid species (e.g., Karanth and Nichols 1998; Heilburn *et al.* 2003; Garrote *et al.* 2010), there has been limited use of trail cameras to detect Canada Lynx. The few studies that have used trail cameras have reported low detection rates compared to other survey techniques, such as snow-track surveys (Crowley *et al.* 2005*; Moen and Lindquist 2006*; Nielsen and McCollough 2009). The mixed success of trail cameras and other survey methods for Canada Lynx may be attributed in part to differences in survey season. Timing should be taken into consideration when surveys for Canada Lynx are conducted. Seasonal differences in the behaviour of Canada Lynx may influence detection success, as Canada Lynx may be more susceptible to attractants during different times of the year.

A uniform and standardized protocol for surveying Canada Lynx across its range would allow comparisons of populations and would be useful in informing decision-making processes regarding management and conservation. As part of a multi-species effort to monitor small- to medium-sized carnivores, we conducted

trail camera surveys from mid-winter to late winter during a time period that coincides with the breeding season of the Canada Lynx (Anderson and Lovallo 2003). We used snow-track surveys to test the efficacy of our camera surveys. Our objective was to determine the detection success of trail cameras during the winter and relate that to changes in Canada Lynx activity. We hypothesized that behaviour of Canada Lynx would vary throughout the winter and that detection would be highest during the breeding season, when Canada Lynx are most susceptible to lure and bait attractants. We further describe trends in behaviour and activity and discuss the implications of our results for the type and timing of surveys for Canada Lynx.

Study Area

The research was conducted in and adjacent to the John Prince Research Forest in north-central British Columbia, Canada (Figure 1). A 16 500-ha portion of forested provincial land 45 km northwest of the town of Fort St. James, the John Prince Research Forest is co-managed by the University of Northern British Columbia and the Tl'azt'en Nation.

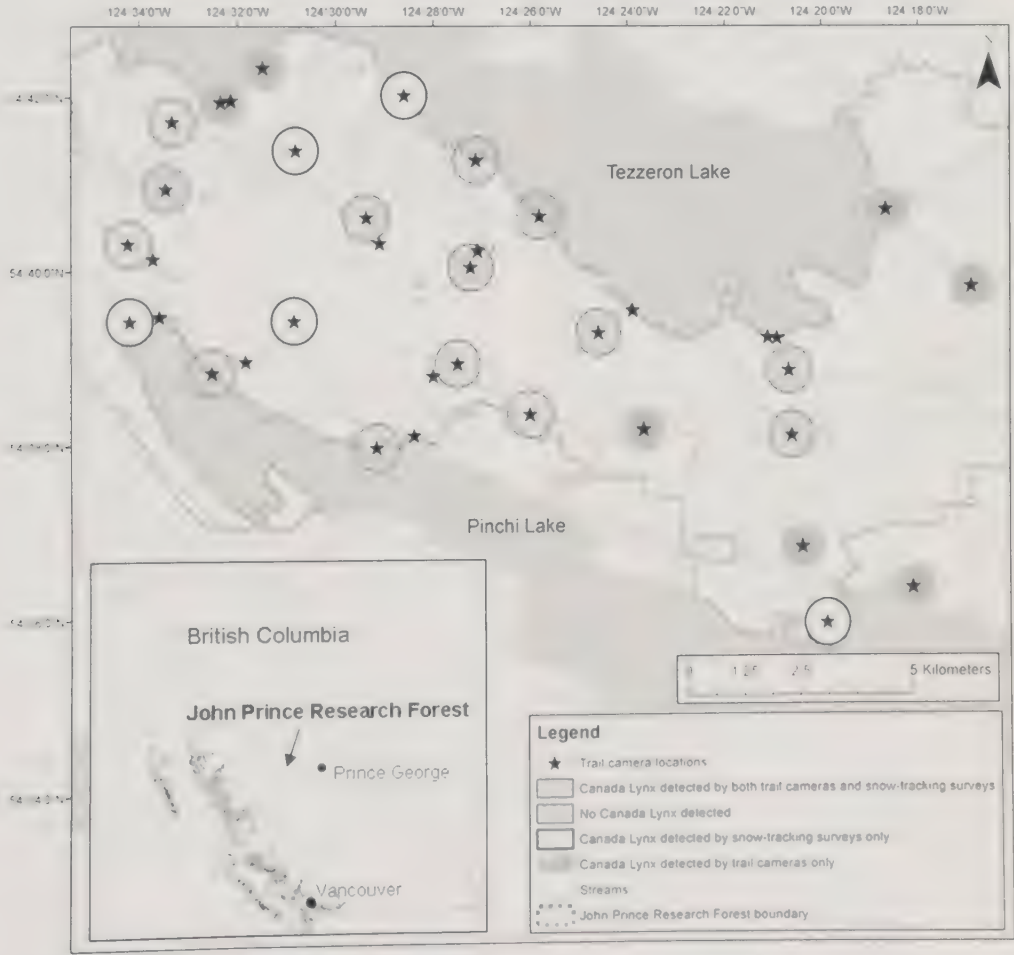


FIGURE 1. John Prince Research Forest, central British Columbia, showing trail camera locations ($n = 37$), snow-track survey zones around camera sites > 1 km apart ($n = 26$), and locations of Canada Lynx (*Lynx canadensis*) detections using trail camera and snow-track surveys, January to April 2013.

The John Prince Research Forest is characterized by rolling terrain with low mountains (700 m to 1500 m above sea level). It represents the northern extent of contiguous Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) forests in the interior of British Columbia and is dominated by the Sub-Boreal Spruce biogeoclimatic zone (Delong *et al.* 1993). The area has experienced a wide variety of logging activities over the past 50 years and contains a mosaic of old and young forest (continuum from new harvest to old growth >250 years old) with interspersed deciduous stands. The stands have a relatively rich understory of deciduous shrubs and regenerating conifers. The research forest is traversed by many small streams that flow into either Tezzeron Lake or Pinchi Lake. Although there are many other carnivore species, the only other felid species that has been observed in the study area is the Cougar (*Puma concolor*), which has been observed only rarely.

Methods

Trail camera surveys

In winter 2013, digital passive infrared trail cameras (Bushnell Trophy Cam model 119467 and Bushnell Trophy Cam HD Max Model 119477, Bushnell Outdoor Products, Overland Park, Missouri) were set for two three-week sessions and one two-week session encompassing the estimated timing of the Canada Lynx breeding season (Anderson and Lovallo 2003), specifically mid-winter (23 January to 12 February), late winter (5 to 25 March), and end of winter (3 to 17 April).

A total of 37 cameras were set in riparian habitat, including lakeshores and streams, throughout the research forest. Twenty-six of these camera stations were spaced >1 km apart (Figure 1) and were used to calculate detection rates and to make comparisons between survey techniques. Riparian corridors were chosen because of their potential use as travel corridors by a multitude of carnivore species.

At each site, a camera was set between 0.5 and 1 m above the snow on a tree or fallen log. Bait and lure were set up near the ground 2 to 3 m from the camera. The bait was a combination of salmon (*Oncorhynchus nerka*) paired with either American Beaver (*Castor canadensis*) or Moose (*Alces americanus*) meat suspended between 0.5 and 1 m above the ground. During the late-winter and end-of-winter surveys, a small diameter log (<15 cm) secured in the snow with one end pointing out directly below the bait (~30 to 40 cm below the bait) was added to the set. The addition of this log served as both a platform for American Mink (*Neovison vison*) and American Marten (*Martes americana*) to stand on and approach the bait as well as an additional solid object that Canada Lynx could sniff, scent-mark, and rub their faces against. Commercial mink lure (Hawbaker's Mink Lure 1, S. Stanley Hawbaker and Sons, Fort Loudon, Pennsylvania) and beaver castor were placed directly above the bait as well as

on the log and ground below the bait. Cameras were checked, bait was replaced, and additional lure was added approximately midway through each session. In general, batteries and memory cards were changed between sessions.

Cameras were set to take 30 seconds of video with a 1-second delay between video-recordings. This schedule allowed for nearly continuous recording of the time an animal was in view. The sensor level was set to normal, LED control for night vision was set to medium, and video sound recording was turned on.

Snow-track surveys

To test the efficacy of trail cameras in detecting Canada Lynx, we conducted two snow-track surveys, the first on 26 and 27 February and the second on 19 and 20 March 2013. Snow-track surveys were conducted within a circle of 500 m radius centered on each of the 26 camera locations that were >1 km apart. Transects between 800 and 1000 m in length generally bisected each circle. Transect lines followed travel corridors, such as riparian streams, shorelines, and old logging roads. Surveys were conducted primarily from snowmobile but included sections traveled by snowshoe where access was difficult. Surveys were conducted 24 to 72 hours after snow had fallen to allow sufficient time for Canada Lynx movements and limit the deterioration of track quality. Every time an observer encountered a Canada Lynx track crossing the transect, the location of the track crossing was recorded on a hand-held GPS (Garmin Rino 530HCx, Olathe, Kansas).

Video data collection

While reviewing video-recordings, we noted the date, time, and location of Canada Lynx detections, the number of video-recordings made per visit, the number of individual Canada Lynx, and whether the video-recording was made during the nighttime or the daytime. Three different behaviours were recorded by the cameras: lure sniffs (a Canada Lynx approached and directly sniffed the lure/bait), scent markings (a Canada Lynx urinated on the lure/bait), and cheek rubs (a Canada Lynx rubbed its cheeks on lure/bait). From these data, we calculated the following performance metrics: detection rate by survey period and week (number of Canada Lynx detections per 100 camera-days) and detection rate by location (proportion of sites where a Canada Lynx was detected).

Spearman's rank correlations were calculated for the number of Canada Lynx detections per 100 camera-days and the week and for the proportion of sites where a Canada Lynx was detected and the week. In all analyses, the level of significance was $P = 0.05$. A detection was considered independent if it was >1 hour since the previous visit by a Canada Lynx to the site. Visits were recorded as a single detection regardless of the number of Canada Lynx present in a group during that visit. We then compared survey detection rates by location

obtained from the cameras and the snow-track surveys to investigate the efficacy of trail cameras in detecting Canada Lynx.

To describe the behavioural characteristics of Canada Lynx through time, we included data from all 37 cameras. As a measure of time spent at a site, we used the number of 30-second video-recordings made of each detection to investigate changes in the length of visits during the winter (i.e., a detection could be composed of one video-recording or several video-recordings, depending on how long the Canada Lynx spent at the site during a single visit).

We also examined the time of day that Canada Lynx were detected at camera sites. We calculated the percentage of diurnal, nocturnal, and crepuscular visits determined visually from video-recording sequences. Nocturnal visits were defined as video-recordings where the infrared light was triggered at night. Diurnal visits occurred when the infrared light did not turn on and the video was recorded in daylight. Lastly, crepuscular visits were defined as a time period when the infrared light turned on in semi-light conditions. Using the time stamp on each video-recording, we further investigated when visits occurred by separating the 24-hour day into eight 3-hour segments. We used a χ^2 test ($P = 0.05$) to determine whether visits by Canada Lynx differed by time of day.

Lastly, as an index of breeding activity, we investigated the relative number of Canada Lynx behaviours observed at sites and how that changed throughout the winter. We calculated the number of Canada Lynx behaviours per 100 detections to measure changes in activity during the season.

Results

Trail camera surveys

The 26 trail cameras used to calculate detection rates recorded a total of 39 Canada Lynx visits (Table 1). These cameras worked properly 97% of the time, providing a total of 1204 working camera-days. Analogous data for the total set of 37 cameras was 48 Canada Lynx visits over 1653 working camera-days (93% of total possible camera time). Camera failures were primarily the result of the sensor level being set on high and depleting the batteries or filling the memory cards.

The number of Canada Lynx detected per 100 camera-days increased for each survey period later in the winter, with 1, 3, and 7 Canada Lynx detected per 100 camera-days for the mid-winter, late-winter, and end-of-winter survey periods, respectively (Table 1). The number of Canada Lynx detected each week also showed an increasing trend, to a seasonal high of 8 Canada Lynx detected per 100 camera-days in the final week of the survey (10–16 April) ($r = 0.92$, $P = 0.011$) (Table 1). The percentage of sites at which Canada Lynx were detected during each survey period increased throughout the winter, finishing with a high of 36% in the week of 10–16 April and a total of 58% for all weeks combined ($r = 0.89$, $P = 0.003$) (Table 1).

Canada Lynx behaviour

Although there was overlap in the confidence intervals, the average number of video-recordings made during each Canada Lynx visit was highest during the weeks in the second half of March (12–25 March) (Figure 2). Visits by Canada Lynx to camera sites throughout the entire season averaged 46%, 48%, and 6% of diurnal, nocturnal, and crepuscular visits, respec-

TABLE 1. Detection rates and working camera-days for trail camera surveys of Canada Lynx (*Lynx canadensis*) in the John Prince Research Forest in central British Columbia, January to April 2013.

Survey	Start date	End date	No. of Canada Lynx detected	Camera-days	No. of Canada Lynx detected/100 camera-days	No. of Camera sites visited by Canada Lynx (n = 26)	Percentage of camera sites visited by Canada Lynx (%)
Mid-winter	23 January	29 January	1	112	1	1	4
	30 January	5 February	2	154	1	2	8
	6 February	12 February	0	154	0	0	0
	Total	23 January	3	420	1	3	12
Late winter	5 March	11 March	3	182	2	3	12
	12 March	18 March	5	180	3	4	15
	19 March	25 March	5	80	6	3	12
	Total	5 March	13	442	3	6	23
End of winter	3 April	9 April	9	173	5	8	31
	10 April	16 April	14	169	8	9	35
	Total	3 April	23	342	7	13	50
	Total all surveys		39	1204	3	15	58

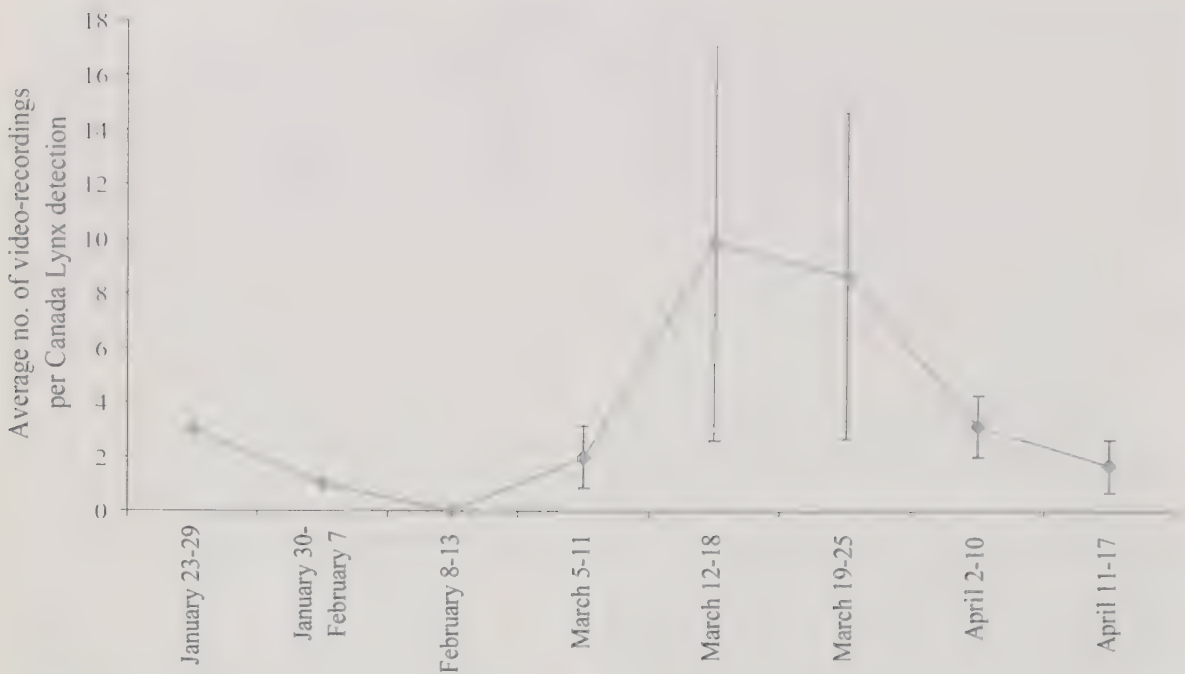


FIGURE 2. Average number of 30-second video-recordings (\pm SE) made of each Canada Lynx (*Lynx canadensis*) visit ($n = 48$) by trail cameras in the John Prince Research Forest in central British Columbia, January to April 2013.

tively. Further breakdown in timing of visits (3-hour time periods) showed there was no correlation between Canada Lynx visits and time of day ($\chi^2_6 = 5.7$, $P = 0.5$). Although not significant, the highest proportion of Canada Lynx visits (22%) occurred in the late afternoon, from 1500 to 1800 (Figure 3). All 5 Canada Lynx detections in which >1 individual (2–4) were recorded on video were observed between 9 March and 5 April 2013.

Cheek-rubbing behaviour was at its highest from early March to early April (5 March–9 April), with a peak in late March (Figure 4). Scent-marking behaviour remained high from mid-March to early April (12 March–9 April) before decreasing again in mid-April (10–16 April). Canada Lynx directly approached and sniffed the lure/bait when visiting a site frequently throughout the majority of the survey; however, the percentage of visits with this behaviour decreased in

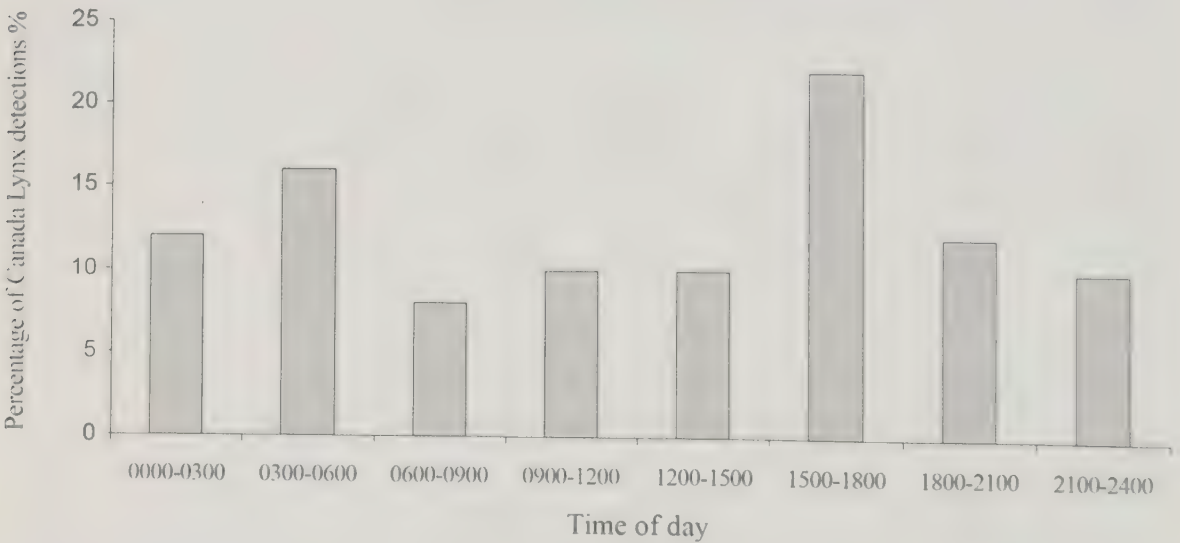


FIGURE 3. Proportion of Canada Lynx (*Lynx canadensis*) visits ($n = 48$) by time of day (all sites combined) recorded by trail cameras in the John Prince Research Forest in central British Columbia, January to April 2013.

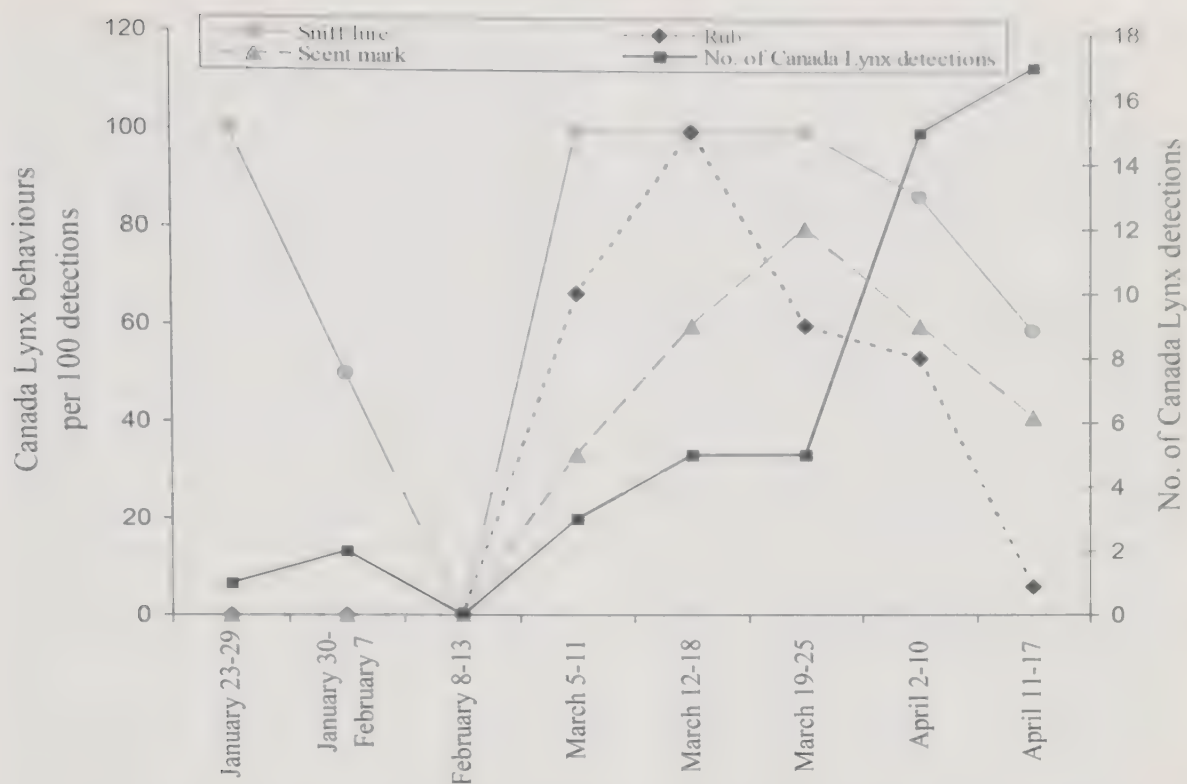


FIGURE 4. Number of detections of Canada lynx (*Lynx canadensis*) ($n = 48$) and behaviours per 100 detections recorded by trail cameras ($n = 37$ sites) in the John Prince Research Forest in central British Columbia, January to April 2013.

each of the last two weeks of the survey, from 2 April to 16 April.

Snow-track surveys

The tracks of Canada Lynx were found during snow-track surveys in 50% of the buffer zones around camera sites (38% of zones in the track survey on 26 and 27 February and 46% of zones in the track survey on 19 and 20 March). The animals were detected by trail cameras at 58% of the sites (Figure 1). Combining the data from both snow-track surveys and the trail cameras, Canada Lynx were detected at 77% of all monitored sites. Although the number of Canada Lynx detected on the snow-track surveys and by the trail cameras was similar, the site locations differed. Canada Lynx were detected on track surveys and by trail cameras at 31% of sites (8 of 26), by track surveys only at 19% of sites (5 of 26), and by trail cameras only at 27% of sites (7 of 26).

Discussion

These results have implications not only for the use of trail cameras but also for any survey technique used to detect Canada Lynx. Differences in detection rates between seasons could lead to misinterpretation of survey results, which are critical to management decisions and actions. Although mark-recapture and occupancy models can account for temporal biases associated with detection rates, confidence in model inputs improves if

the probability of detection increases. An understanding of an animal's ecology and how it influences seasonal detection rates is needed to reliably interpret the results of wildlife surveys. This information can inform study designs and protocols to ensure that surveys are conducted during the most appropriate and efficient time periods.

The detection rates for each survey period in this study (mid-winter, late winter, and end of winter) showed considerable variation (from 1 to 7 Canada Lynx detected per 100 camera-days), with the higher rates being notably greater than rates reported by surveys in other areas. The only peer-reviewed published study using trail cameras for Canada Lynx reported a detection rate that was lower than camera surveys for other felid species (2 Canada Lynx detected per 100 camera-days) (Nielsen and McCollough 2009). Unpublished reports of camera surveys for Canada Lynx populations in Maine and Minnesota reported even lower detection rates, with 1 Canada Lynx/100 camera-days (Crowley *et al.* 2005*) and zero detections in 512 camera-days (Moen and Lindquist 2006*), respectively. Compared to the Bobcat (the only other North American felid of similar size whose range overlaps the range of the Canada Lynx), our highest detection rates were greater than or equal to other studies (4 to 7 Bobcats/100 camera-days) (see Harrison 2006 and Heilbrun *et al.* 2006). In Vermont, Bobcats were detect-

ed at only 5.4% (3/56) of camera sites in a total of four survey weeks (Long *et al.* 2007).

One explanation for the high detection rate in this study is that surveys using trail cameras or hair snares for Canada Lynx are often conducted in the late summer and fall (McDaniel *et al.* 2000; Burdett *et al.* 2006*; Nielsen and McCollough 2009). Throughout the United States, the National Lynx Detection Protocol was deployed primarily in the fall using hair snare grids set out in areas with known or potential Canada Lynx populations (Burdett *et al.* 2006*). Although there have been limited survey efforts during portions of the winter season (Crowley *et al.* 2005*; Burdett *et al.* 2006*; Moen and Lindquist 2006*), surveys for Canada Lynx using trail cameras have not been conducted during the breeding season with the survey intensity and duration used in this study.

Canada Lynx generally breed in March and April throughout their range; however, the exact timing in different regions is not well understood (Anderson and Lovallo 2003). In Maine, the success of trapping Canada Lynx in cages typically increases during the winter as the season progresses from January to March (SMC, personal observation). In addition, hair-trapping sessions for Eurasian Lynx (*Lynx lynx*) have been more successful during a time period that coincides with their breeding season (Schmidt and Kowalczyk 2006).

The increase in detection rates over the course of the current study was likely due to the onset and peak of breeding activity. As the season progressed from January through March, the Canada Lynx were not only detected more often by camera, but they spent more time at camera sites scent-marking and cheek-rubbing.

Our results are especially relevant to surveys that rely on the cheek-rubbing behaviour of Canada Lynx to collect hair samples on hair snares. Cheek-rubbing behaviour remained high from early March to early April, with lower levels both before and after this time period. Detection probabilities determined from these data would most likely increase if hair-snare surveys were conducted during the time period that coincides with the Canada Lynx breeding season. Mark-recapture surveys that rely on the re-sighting of marked individuals by cameras might also benefit from being conducted during this time of the year, especially in mid-March to late March, when Canada Lynx spent more time at camera sites. Increased time in front of the camera provides additional opportunities for the identification of individuals using unique natural or human-made markings.

Although detection rates were highest in mid-April, Canada Lynx spent little time during this period at the camera sites performing cheek-rubbing or scent-marking behaviour. One explanation for this pattern of visitation may be a combination of seasonal changes in Canada Lynx ecology that include the end of breeding activity, the break-up of the previous year's family groups, and the start of dispersal (Anderson and Lovallo

2003). In contrast to the previous few weeks, all visits to camera locations during this period were made by individual animals and did not include family groups. Detections at camera sites from mid-March to early April often included groups of multiple individuals. Winter distribution patterns may be changing during this time of the year, influencing survey results. Caution should be used in interpreting results obtained during the end of winter period, when Canada Lynx detections may be influenced by a young and transient portion of the population.

At a smaller time scale, Canada Lynx were active at camera sites equally during nighttime and daytime. Although not significant, the highest amount of activity at camera sites occurred during late afternoon and early evening, similar to an activity peak in a Montana study in which Canada Lynx were equipped with motion-sensitive radio-collars (Kolbe and Squires 2007). The combined measures of behaviour used in the current study provide additional insight into the seasonal and daily activity patterns of Canada Lynx that can influence the success, timing, and interpretation of detection surveys.

To address our objectives, we also determined the relative efficacy of trail cameras and snow-tracking surveys. Although we found that the number of sites with Canada Lynx detections was similar for each method, only 31% of sites with Canada Lynx detections were in both survey techniques. Additional snow-track surveys in the last week of March or early April, when camera detections were highest, might have increased our detection rates. Snow-track surveys during this time period, however, were not a possibility because of poor tracking conditions. Also, our study generated comparisons on a small spatial scale, relative to the spatial requirements of Canada Lynx. If we were to increase our spatial scale, the detection success with both techniques would likely increase. For example, if we lay a 5 km² grid over our study site, 80% of the grid cells (8 of 10) have Canada Lynx detections from both snow-track surveys and trail cameras and 100% have detections from one of these techniques. Even at the smaller spatial scale used in the surveys (1 km²), 77% of sites have Canada Lynx detections with at least one of the survey techniques.

Although we found that trail cameras are a viable option for surveying Canada Lynx during the breeding season, the combination of both trail cameras and snow-tracking surveys was especially effective. Trail cameras should be considered as a complementary technique to snow tracking to increase survey efficacy, maximize detection probabilities, and cross-validate survey techniques. In areas where it is difficult or impossible to conduct snow-track surveys, trail cameras may be used as an alternative.

The majority of Canada Lynx studies have occurred in the northern boreal forest or on the extreme southern edge of their range (e.g., Koehler 1990; Poole 1995;

Slough and Mowat 1996; Vashon *et al.* 2008). There is therefore limited information on the ecology and status of Canada Lynx populations in central British Columbia, and we have very little information about Canada Lynx densities in the study area during the survey. Although the detection rates for Canada Lynx were high, detection rates would likely vary with fluctuations in Canada Lynx densities (Squires *et al.* 2012). For this reason, it is difficult to determine whether the overall detection rate in this study was a result of survey design (i.e., using riparian corridors, attractants), naturally high densities of Canada Lynx, movement of Canada Lynx into the area due to timber harvesting and habitat loss in the area surrounding the John Prince Research Forest, or a combination of any of these factors. The temporal trend in detection success observed in the study, however, is likely a product of ecological determinants in the life cycle of the Canada Lynx that would remain consistent with fluctuations in Canada Lynx densities.

Assessing the influence of temporal and spatial factors on the efficacy of detection surveys is critical to improving study designs and protocols (Zielinski and Kucera 1995). Depending on survey objectives, it may be beneficial to use trail cameras as well as other non-invasive methods to survey for Canada Lynx from early March to early April, when survey efficacy and detection rates can be expected to be at their highest.

Estimates of Canada Lynx distribution, relative abundance, and habitat selection derived from detection surveys can be misinterpreted if seasonal changes in behaviour and its influence on detection are not taken into account. Occupancy models where the probability of detection is <1 are used with increasing frequency to determine species distribution (MacKenzie *et al.* 2002; O'Connell *et al.* 2006; Bailey *et al.* 2007). Our results not only demonstrate the importance of estimating the detection probability, but also take into account the influences of seasonal variation on detection success. Incorporating such variation into study design and analysis will decrease bias and increase the power of a survey to detect spatial and temporal trends or patterns in distribution and abundance.

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Invasion of *Rosa rugosa* (Rugosa Rose) into Coastal Plant Communities of Brier Island, Nova Scotia

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During August and September 2010, we surveyed the entire 20.4 km perimeter of Brier Island, Nova Scotia, for the invasive shrub *Rosa rugosa* (Rugosa Rose). This island in the outer reaches of the Bay of Fundy of Nova Scotia is geographically isolated and relatively undeveloped. Our objective was to determine the extent and mechanism of the invasion of *R. rugosa* into different coastal habitats to gain insight into the potential threat to native biodiversity from the unchecked population growth of this monopolizing, rank shrub. Over 300 colonies of *R. rugosa* with mean height over 1 m occupied 2089 m of the island perimeter within 10 m of the top of the beach. The mean distance between colonies was about 61 m and the maximum distance was 1927 m. At least 33 colonies formed almost impenetrable walls, each over 10 m in length, and 2 colonies occupied about 500 m² each. *Rosa rugosa* had greatest density on a sand–gravel beach on which 88 colonies occupied 22% of the area and 33% of the beach margin. Exponential growth of the population (inferred from aerial photographs from 1970, 1988, and 2000) may be due to the various systems of seed dispersal. Agents include primary (American Mink, *Neovison vison*, and Red Squirrel, *Tamiasciurus hudsonicus*) and secondary (an unidentified rodent) biotic dispersers. Longer distance dispersal may include Coyotes (*Canis latrans*), off-road vehicles and deposition of fruits by currents and waves. The main sites of seedling establishment are native habitats, such as dune grass and seashore Seaside Plantain (*Plantago maritima*) zones, albeit modified by this exotic rose. Dispersal of colonies contradicts a hypothesis of dispersal from human habitation along roads and tracks to the coastal habitats. We conclude that *R. rugosa* is having a significant impact on marine coastal plant communities and has the potential to dominate windswept shrub habitats on coastlines of much of Nova Scotia.

Key Words: *Rosa rugosa*; Rugosa Rose; coastal habitats; off-road vehicles; plant invasions; Brier Island, Nova Scotia

Rosa rugosa Thunb., Rugosa Rose, is native to north-eastern Asia and has become widely distributed in both North America and Europe following escape from cultivation as an ornamental shrub and active planting to manage seashore erosion (Bruun 2005, 2006; Isermann 2007; Hill *et al.* 2010). The native habitat in Asia includes coastal environments (Bruun 2005). *Rosa rugosa* is tolerant of environmental extremes of drought, fire, salinity, uprooting, and burial by sand (e.g., Belcher 1977; Augé *et al.* 1990; Tsuda *et al.* 1999; review by Bruun 2005; Kollmann *et al.* 2011), providing key adaptations for its success as an invasive species.

There is extensive literature on the spread of *R. rugosa* in Europe, particularly around the Baltic Sea and the North Sea, where it has become invasive in coastal habitats and especially in sand dune systems (Fremstad 1997; Didriksen 1999; Isermann 2007; Kollmann *et al.* 2007; Isermann 2008a, 2008b, 2008c; Jørgensen and Kollmann 2009; Damgaard *et al.* 2011; Hantson *et al.* 2012). Less attention has been paid to *R. rugosa* in North America, although Bicknell (1911) provided an initial account of its invasive properties in northeastern North America based on observations in Nantucket. The species is widespread in eastern Canada (Darbyshire 2003), and Hill and Blaney (2010) suggested that *R. rugosa* is among the adventive species likely to be major invaders of coastal habitats of eastern Canada.

Fernald (1921) first described *R. rugosa* as a naturalized plant in Nova Scotia from Yarmouth County, at the southwestern corner of the province. Herbarium records and incidental field observation by the current authors show that the species is widely distributed in Nova Scotia; however, no detailed study of the species has been undertaken in seashore habitats in the province, except for a recent survey of coastal sand dune barrier beach systems facing the Gulf of St. Lawrence (Hill *et al.* 2010). There, 45% of 24 beach systems were colonized, and *R. rugosa* covered up to 8.8% of beach area.

Since the native habitat of *R. rugosa* includes coastal marine communities in addition to sand dunes (Bruun 2005), we decided to survey a defined area of Nova Scotia where rocky headlands and shrub communities predominated. Brier Island was selected because it is a discrete system that is relatively undeveloped and its shorelines are easily accessed. This island provides a microcosm of the coastal region of much of Nova Scotia and adjacent New Brunswick and New England because of its wide diversity of habitat types that include: sand and rocky shore, barachois (brackish ponds), cliffs, sheltered bays and exposed points.

Our primary objective was to evaluate the extent to which *R. rugosa* was colonizing a small island and to anticipate colonization elsewhere on this basis. In addi-

tion to determining the extent of colonization, we investigated the differential ability of *R. rugosa* to colonize different plant communities and the potential vectors responsible for colonization events.

Given the likely colonization starting from garden plantings in Westport village, we hypothesized that a natural gradient of colony sizes and densities around the island might be reconstructed, with Westport as the origin, as per Jørgensen and Kollmann (2009).

Methods

Study site

Brier Island is an isolated island in the Bay of Fundy of Nova Scotia (Figure 1). It is about 6.9×2.7 km in maximum dimensions, with a perimeter of about 20.4 km (Figure 2A). The island has a major axis running from northeast to southwest. The northwestern shore is extremely wind exposed, and the more protected eastern shore faces adjacent Long Island. The extreme tidal amplitude (regularly greater than 5 m) and narrow passage between Brier Island and Long Island result in strong currents as well as high wind and wave exposure that would facilitate dispersal of fruit (hips) of *R. rugosa*.

Brier Island is at the southwestern tip of an extensive basaltic formation that extends for at least 200 km along Long Island, Digby Neck, and the North Mountain of the Annapolis River valley (Roland 1982; Davis and Browne 1996). Brier Island has a single small village, Westport, a traditional fishing community with a tourist industry based largely on whale and bird watching. There is currently little agriculture on the island, and most of the terrestrial landscape consists of coastal

barrens, boreal forest (with spruces, *Picea* spp.; Balsam Fir, *Abies balsamea* (L.) Mill; and Green Alder, *Alnus viridis* (Chaix) de Candolle) and extensive wetlands. Most of the shoreline consists of outcrops of basaltic bedrock with large boulder fields and occasional sand or gravel beaches. The relatively undeveloped shorelines (except in Westport) consist of abandoned farmland in various stages of succession and other, more natural, habitats. These shorelines have become modified by an extensive network of trails used by off-road vehicles and coastal hikers; these trails are ideal for surveying the extent of colonization by *R. rugosa*.

We divided the island perimeter into 10 sections (labelled clockwise A–J), with each section representing distinctive habitat or topographic features (see Figure 2A and Table 1) or suitable survey units. The village of Westport was considered as two sample segments: J represented the actual seafront with its apparently wild colonies of *R. rugosa* and J' included the formal plantings and roadside colonies not associated with the seashore.

Historical reconstruction

To reconstruct the timing of colonization of *R. rugosa* around the island, we used aerial photos from 1970 (1:12 000), 1988 (1:10 000), and 2001 (1:10 000) provided by Service Nova Scotia and Municipal Relations (<http://www.gov.ns.ca/snsmr/land/products/air2.asp>). These were compared with images from Google Earth (2010) and our colony map from 2010.

Sampling of coastal habitats

We surveyed almost the entire 20.4 km coastline of Brier Island by walking along roads and coastal trails

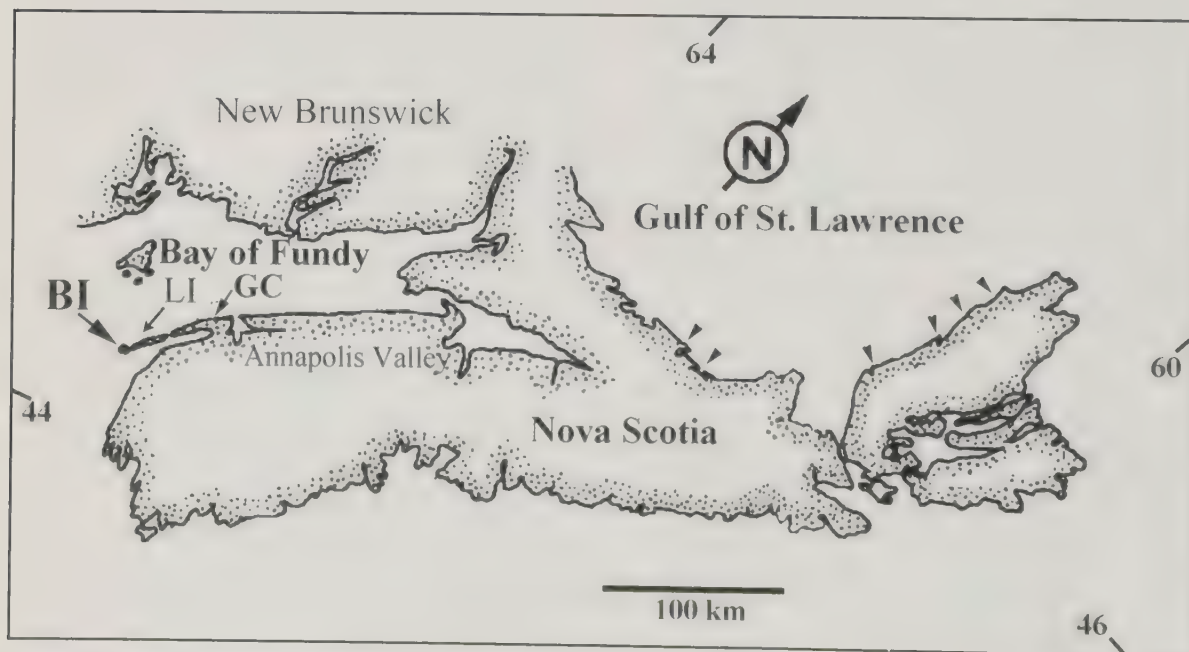


FIGURE 1. Map of Nova Scotia showing the location of Brier Island. The barrier beach sand dune systems in the Gulf of St. Lawrence where *Rosa rugosa* (Rugosa Rose) has colonized (Hill *et al.* 2010) are marked by arrows. Abbreviations BI, LI, and GC refer to Brier Island, Long Island, and Gulliver's Cove.

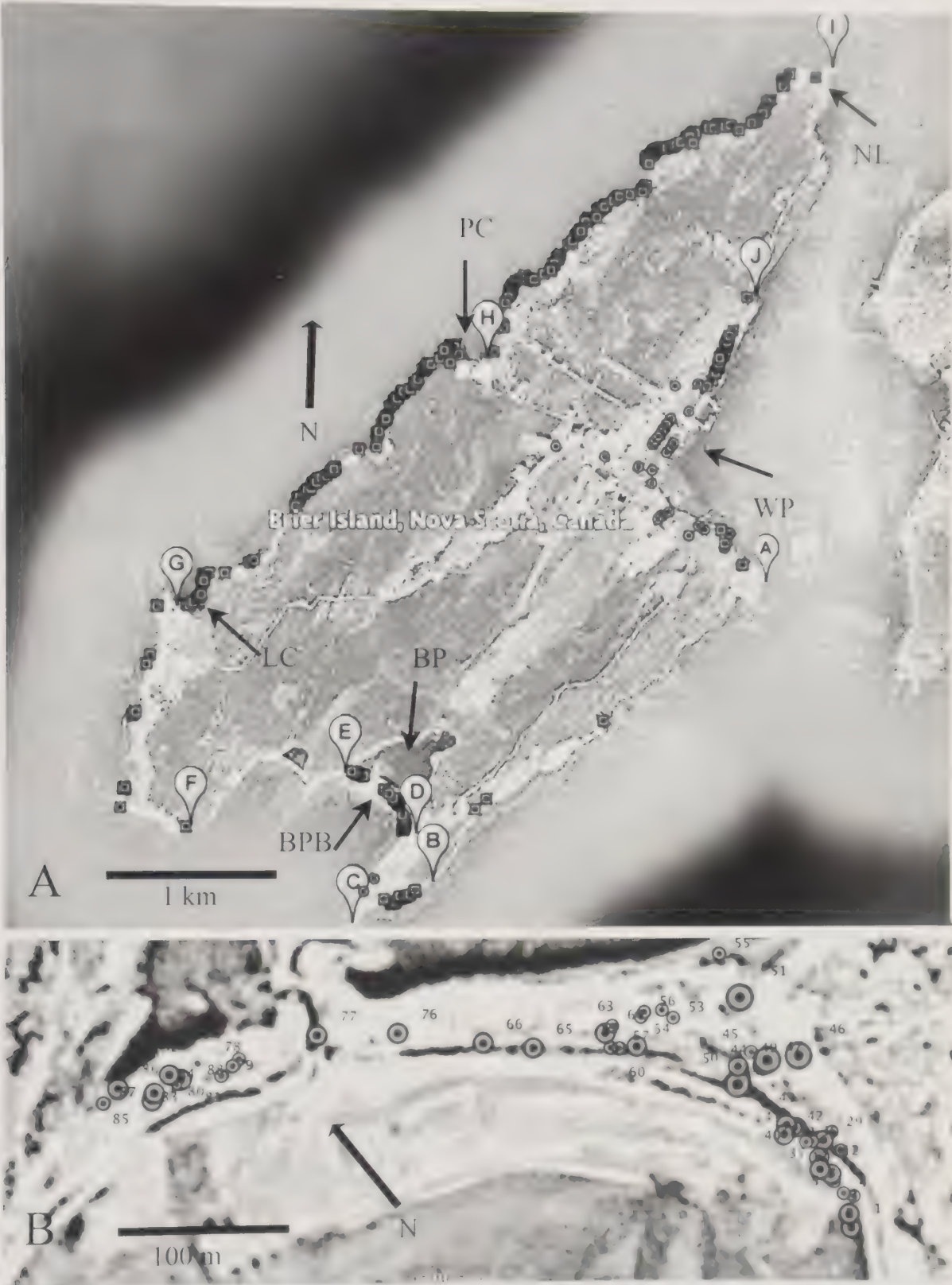


FIGURE 2. A. Image of Brier Island, Nova Scotia, from Google Earth in 2010 indicating shoreline reaches (clockwise starting at A) and locations of individual clumps of *Rosa rugosa* (Rugosa Rose) within 10 m of the top of the beach (squares) and colonies further than 10 m away or obviously associated with human planting (circles). Shoreline segment D (Big Pond Beach) is enlarged in B. Shoreline segments correspond to Table 1. Abbreviations PC, WP, NI, BP, BPB, and LC refer to: Peajack Cove, Westport (village), North Light, Big Pond, Big Pond Beach and Lighthouse Cove. B. Google Earth image of Big Pond Beach (shoreline segment D) with approximate locations of all colonies plotted based on area (size categories for symbols from smallest to largest: <1 m², 1–10 m², 11–100 m², >100 m²).

TABLE 1. Principal habitats occupied by *Rosa rugosa* (Rugosa Rose) on Brier Island, Nova Scotia, in August and September 2010, conspicuous sites for seedling development, and vegetation in adjacent coastal uplands in the 10 shore reaches (see Figure 2A for locations of each shoreline segment and Table 2 for characterization of the extent of colonization of each area).

Shoreline segment	Adjacent coastal upland	Principal <i>Rosa rugosa</i> habitat	Regeneration habitat	Occurrence of <i>Rosa rugosa</i> seedlings (% of sites) ¹
A	Spruce forest, old field	<i>Rosa rugosa</i> uncommon	N/A	
B	Old field	Old field	Off-road vehicle disturbance?	Not evaluated
C	Old field	Old field	Off-road vehicle disturbance?	Not evaluated
D	None (lagoon)	In sand/cobble of barrier beach	Under <i>Rosa rugosa</i> adults	Occurrence = 55%
E	Spruce forest, Green Alder thicket, steep unstable cobble	<i>Rosa rugosa</i> absent	N/A	
F	Old field	Wrack line on cobble, old field	Off-road vehicle disturbance? (episodic)	Occurrence = 0%
G	Spruce forest, rank vegetation in seeps, narrow old field	Old field, wrack line on cobble, bluffs	Bluff crevices, salt spray zone, off-road vehicle disturbance	Occurrence = 6%
H	Old field, low heath, bluffs	Old field and heath, salt spray zone, bluffs and gullies	Salt spray zone (gravel with <i>Plantago maritima</i>)	Occurrence = 25%
I	Spruce forest, Green Alder thicket, old field	<i>Rosa rugosa</i> absent	N/A	
J	Gardens, seawall, waste places	Gardens, seawall, wrack line on cobble, ditches	Not evaluated	

¹Seedling occurrence refers to the percentage of *Rosa rugosa* bushes that had *R. rugosa* seedlings (first- or second-year stages) within 2 m of their margin.

in August and September 2010. A total of about 1 km of shoreline was inaccessible, part in an area with high coastal cliffs where spruce forest came to the cliff edge and part in an area that was signposted as private. These areas were not surveyed, but they were partially scanned from a distance with binoculars, and no *R. rugosa* was observed.

The location of each colony of *R. rugosa* within 10 m of the top of the beach was noted with GPS (eTrex, Garmin, Olathe, Kansas). The length of each colony parallel to the shore, its maximum dimension perpendicular to the shore, and maximum height were measured, and the cover was estimated. While additional colonies were noted, only the largest colonies parallel to the shoreline were measured. Thus, at any one position we did not measure smaller colonies closer to or further from the seashore.

Where multiple colonies overlapped, we measured the maximum linear extent of the combined colonies and then estimated overall cover. Where colonies had clearly fused (i.e., with a mixture of red and white flowers), these were counted as one. Thus our estimate of colony numbers is an underestimate of establishment events. Furthermore, since larger colonies are typically taller, our values for maximum colony height are likely an underestimate of overall colony stature (large

colonies would be given only a single height value).

The island perimeter was considered as 10 shoreline reaches. In addition to the colony census, the vegetation type associated with each reach was recorded. We used these data to determine the differential ability of *R. rugosa* to colonize different landscape forms and naturally occurring plant communities. These data informed our understanding of seedling occurrence and provided the basic description of the various reaches found in Table 1. Distance between colonies was estimated after the GPS locations of the colonies had been plotted onto an image from Google Earth (Google Inc. 2010) and the image had been enlarged. We then used the path length tool to estimate distance at a resolution of 0.1 m.

Sampling at Big Pond Cove

In addition to mapping the perimeter of the island, we undertook more comprehensive mapping at a single site to document the ability of *R. rugosa* to spread in two dimensions over a landscape. This small area, at Big Pond Cove, was a cobble–sand beach system at the southwestern corner of the island (segment D). It was bounded on the seaward side by an extensive cobble–sand beach in the intertidal zone and on the landward side by a brackish lagoon (Big Pond). A conspic-

uous dune system was absent, and the slightly raised ridge facing the shore was about 1 m in elevation above the water level in Big Pond. The system was about 600 m long and varied from about 50 m in width at the western end to about 120 m in width at the eastern end, where it merged into a more terrestrial landscape of Green Alder and spruce scrub.

Detailed mapping of the *R. rugosa* colonies was made using a hand-held GPS. Each colony was measured (length, width, maximum height), and the flower colour was recorded (pink or white). Beach area was determined from Google Earth as 32 000 m².

The seashore and beach survey included the entire population within the defined sampling spaces. Hence these are not sample estimates, but measures of the entire population. Consequently, the measure of population standard deviation is sigma (σ) rather than the typical sample standard deviation (s) used to describe sample dispersion (Sokal and Rohlf 1995).

Observations of seed dispersal and establishment

Observations were made on the state of rose hips, seeds, and seedlings in populations along the island's western and southern shores (shoreline segments D to H on Figure 2A). Basic data were needed to fill in information on the processes that may contribute to the rapid spread of this species on Brier Island. Accordingly, distance measurements were taken of detached whole hips and seeds from the nearest adult rose for 6 bushes growing on a cobble beach on the eastern shore of Lighthouse Cove (at the southern end of segment G) where the scatter of seeds showed that dispersal was well under way. This is a low-lying coast, and the inland edge of the bushes merges with rank vegetation at the edge of lagoon pools. Predation of the scattered seeds was prominent at Peajack Cove (at start of H on Figure 2A), and the level of predation among the scattered hips for 6 bushes was recorded. Mammal scats were encountered during the seedling survey and 6 were collected, dissected and the seeds in the scats were identified.

The terrain in the vicinity of adult bushes of *R. rugosa* was scrutinized for the presence of seedlings. The percentage of bushes with *R. rugosa* seedlings nearby was calculated for the various areas investigated (shoreline segments D through H). Seedling hotspots were identified in segments D and H, but for other areas where *R. rugosa* was common (e.g., segment G) or scattered (e.g., segment F), no mechanism was discovered that might account for the generation of new *R. rugosa* clumps. For the clumps encountered in the regeneration survey, we calculated the proportion that were located beside an off-road vehicle trail.

Results

Historical reconstruction

The large colony of *Rosa rugosa* to the west of North Light, clearly visible on Google Earth, corresponds to an expanse of shrubbery that was present in the 2001

and 1988 aerial photographs, but was absent in 1970. The resolution for Brier Island on Google Earth is insufficient to resolve the *R. rugosa* colonies at Big Pond Beach. What are likely *R. rugosa* colonies at Big Pond Beach can be distinguished in the 2001 aerial photographs, but the colonies are fewer. The large continuous expanses present in 2010 are absent in the 2001 aerial photographs. The 1988 and 1970 aerial photographs show no large vegetation on Big Pond Beach.

The aerial photographs revealed a major change in the landscape between 1970 and 2001. In 1970, there was no evidence of the network of off-road vehicle trails around much of the island perimeter. These trails were conspicuous in the 1988 aerial photographs and become successively more developed by 2001 and 2010. These trails are used by island inhabitants in the collection of wild berries (e.g., berries of the Large Cranberry, *Vaccinium macrocarpon*) on the coastal heathlands, Common Periwinkles (*Littorina littorea*) in the rocky intertidal zone, and presumably for recreation.

The large isolated colony of *R. rugosa* at the northern tip of Brier Island was 40 m long in 2010. By calibrating the dimensions of this colony with reference points in Google Earth, we calculated that this colony was 34.6 m long in 2001 and 26.2 m long in 1988. Accordingly, the growth rate of this colony was 0.7 m year⁻¹ between 1988 and 2001 and 0.6 m year⁻¹ between 2001 and 2010. If the five largest colonies in the 2001 aerial photographs of Big Pond Cove (segment D) are the same colonies as the largest ones in 2010, colony size increased from 10 m (SD 5) to 31 m (SD 17). This gives an apparent growth rate of 2.3 m year⁻¹; however, this high rate may be the result of fusion with adjacent colonies not resolved in the 2001 aerial photograph.

The perimeter of Brier Island

Colony number and inter-colony distance: In our almost complete 20 km survey of the shorelines of Brier Island, we noted over 300 colonies of *R. rugosa*, which comprise 10.2% of the island perimeter (Table 2). The largest run of shoreline devoid of *R. rugosa* was 1750 m (shoreline segment I), where dense *Alnus* and *Rubus* (raspberry, blackberry, and dewberry) thickets occupied the top of the shoreline along a cliff. This site might represent a farm that was abandoned prior to the introduction and naturalization of *R. rugosa*. The density and height of the vegetation would have made colonization by *R. rugosa* difficult. Segment C had two *R. rugosa* colonies (Figure 2A), but these were over 10 m from the top of the beach and were not included in the perimeter enumeration.

Distance between colonies was highly skewed in favour of short distances, suggesting a clumping of colonies and secondary spread following initial colonization. The median distance between colonies was <25 m, with 14.5% of colonies being separated by <5 m (Figure 3A). There were only 5 inter-colony gaps of >1000 m.

TABLE 2. Distribution of *Rosa rugosa* (Rugosa Rose) around the perimeter of Brier Island, Nova Scotia, in August and September 2010, within 10 m of the top of the beach. See Figure 2A for areas covered in this table. Note distance between colonies is uncorrected for colony size, but is based on point GPS coordinates. Standard deviation is in parentheses.

Shoreline segment	<i>Rosa rugosa</i>				
	Shoreline segment length (m)	Number of colonies	Sum of colony length (m)	Mean distance between colonies (m)	Percentage of segment perimeter occupied by <i>Rosa rugosa</i> (%)
A	3 260	3	8	1 014 (912)	0.02
B	680	24	98	87 (202)	14.4
C	770	0	0	—	0
D	630	29	236	20 (31)	37.5
E	1 420	0	0	—	0
F	2 310	11	68	218 (241)	2.9
G	3 260	77	822	42 (71)	25.2
H	3 630	133	723	30 (44)	19.9
I	1 750	0	0	—	0
J	2 730	25	134	93 (270)	4.9
Total	20 440	302	2 089	60.8	10.5

The average distance between colonies was about 61 m (Table 2). This number is an overestimate, as it does not take colony size into account; including colony size would reduce the inter-colony distance to 54 m. These are also conservative estimates of inter-colony distance, as we considered only colonies on a continuous line parallel to the shore, and only the largest of these were measured. Hence smaller colonies that overlapped with larger ones were not measured, and no zero values for inter-colony distances were recorded. This average also includes shoreline stretches (e.g. eastern island, segment A) where *Rosa rugosa* is uncommon and where large inter-colony distances (viz. 1927 m, the island maximum from segment A) further inflate the average inter-colony calculation.

Colony length: Colony length was highly variable and ranged from less than 1 m to 116 m. Over one-third of the colonies were <3 m long, and about one-fifth of colonies were >10 m in length (Figure 3B). Average length of colonies ranged from 2.8 m in segment A to 10.7 m in segment G (Table 3). Five of the segments had colony lengths on a continuum from 4.1 m to 6.2 m with differences between segment averages of <1 m. There were larger differences in length between segments F and D (1.9 m) and between segments D and G (2.6 m). Until colonies are aged, it is not possible to determine whether colony size in the different segments represents adaptations to different environments (e.g., wind exposure) or differences in time of colonization.

Colony height: The different segments had a wide range of colony heights (Figure 3C). The large histogram peak at 150–159 cm (approximately 1.5 m) and the smaller surrounding values in Figure 3C are artifacts of approximating maximum height in colony interiors. Colony height in different segments ranged from 74 cm (SD 45) in segment H to 151 cm (SD 47) in segment J (Table 3).

The shortest colonies were in the open heathland (segments B, F, G, and H) and at the A site (Table 3). In segment H, these short colonies were associated with an open shrub community on the portion of the island with the most wind exposure (Table 3). Other shoreline segments with open heathland were B, F, and G, where *R. rugosa* was conspicuously shorter than in the colonies in the village of Westport. Outside Westport, the tallest colonies occurred either on the sand beach system in segment D (note large standard deviation) or in a narrow band between the top of the shore and the start of spruce forest in segment G. In both of these segments, many colonies were over 2 m in height. There were few regeneration opportunities for *Rosa rugosa* along the sheltered but unsettled, A segment coastline (n=3 bushes) and the mean colony height was low. There are cliffs along much of the A coastline and this area has succeeded in conifer forest and thick shrub (e.g., Wild Raisin, *Viburnum nudum* L.; and Speckled Alder, *Alnus incana* (L.) Moench).

Colony area: There was an extreme range in colony size on Brier Island. About one-third of colonies were less than 5 m² in area, one half were under 10 m² (Figure 3D), and a twentieth of colonies occupied over 100 m². Other than segment A, which had only three plants, with a mean of 6.4 m² (Table 3), the smallest colonies were found in Westport. There was little difference between the planted beds and hedges and the apparently wild colonies along the shorefront (both about 10 m²). The remaining segments had much larger colonies, ranging from 22.7 m² in segment B to 69.5 m² in segment G. Even when corrected for cover, segment G, with 48.1 m², had the largest colonies. Large differences between area and area corrected for cover within a segment (Table 3) are based on either extensive marginal growth of established colonies or establishment of many new colonies within a general area.

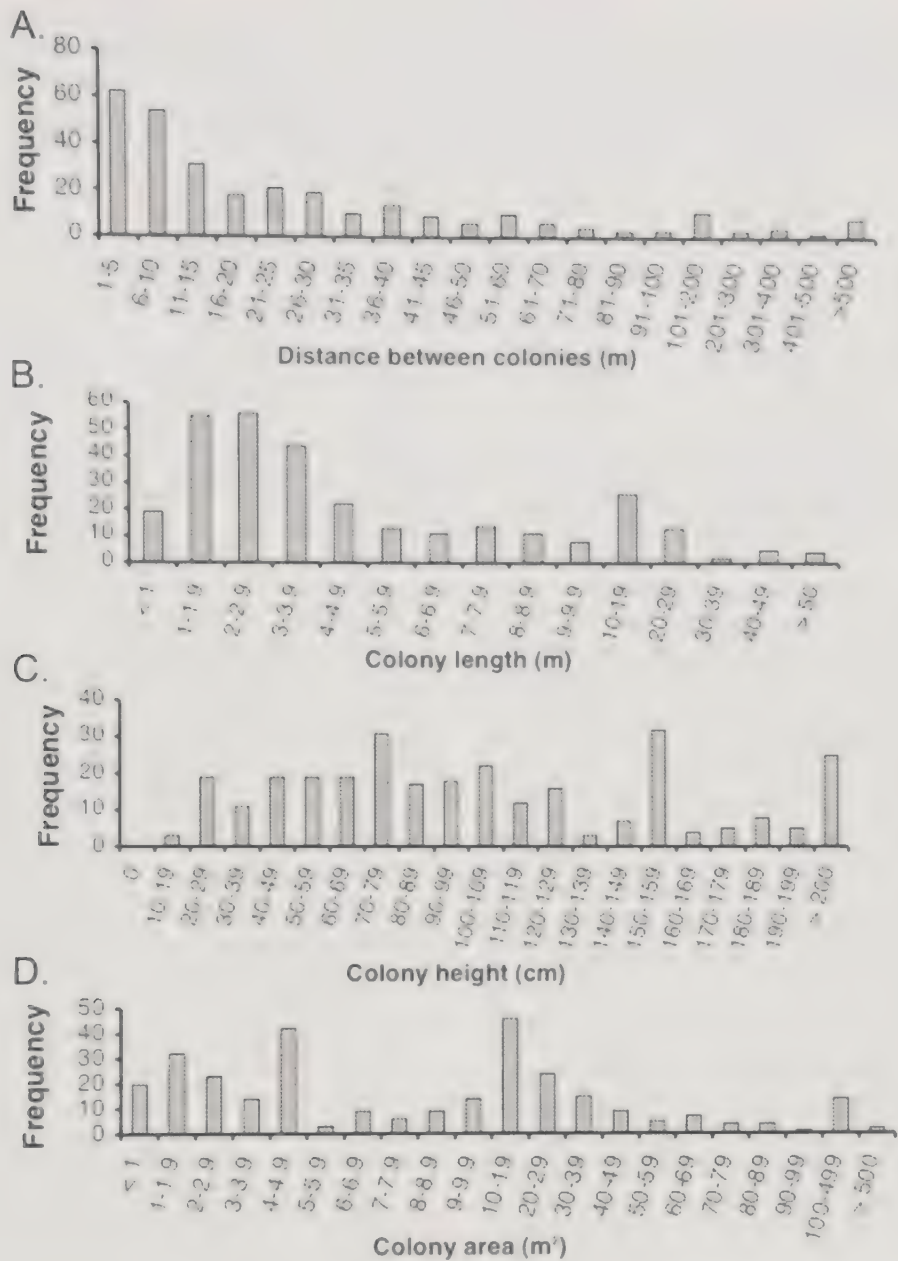


FIGURE 3. Morphometric analysis of *Rosa rugosa* (Rugosa Rose) colonies on Brier Island, Nova Scotia, in August and September 2010, indicating frequency distributions. A. Distance between colonies. B. Colony length. C. Colony height (the high frequency of heights in category 150–159 is based on approximation from margin of colony when direct measurement could not be made). D. Colony area. Note changing scale along the x axis for A–D.

Westport Village (area J’): Aside from the 25 naturalized colonies of *R. rugosa* measured along the immediate shoreline of Westport (shoreline segment J) (Table 2), 29 colonies were observed in the village that were associated with obvious plantings in garden beds or hedges. At 183 cm (SD 27), these were the tallest colonies (Table 3). Furthermore, surrounded by lawns or driveways, etc., these colonies were limited in their ability to spread; thus they all had 100% cover. Many shoreline colonies in the village (segment J) also attained an equivalent height, but the shorter average

height and greater variation in heights (151 cm, SD 47) (Table 3) reflect continuing colonization of the shorelines. These plants on the lee side of the island were also in protected habitats beside houses and would have been under considerable care. The cultivated colonies (segment J’) also had the smallest variance, likely a response to the absence of juvenile *R. rugosa*.
Big Pond Cove: The shore that was surveyed at Big Pond Cove (Figure 2B) was about 32 000 m². Other than *R. rugosa*, there was little woody vegetation. *Rosa virginiana* (Virginia Rose) was rare, and there were

TABLE 3. Summary of morphometric features of colonies of *Rosa rugosa* in different shore reaches of Brier Island, Nova Scotia, in August and September 2010. Shoreline segments C, E, and I had no colonies of *R. rugosa* within the prescribed areas; J' indicates cultivated colonies in Westport village. See Table 2 for the number of colonies in each segment. Standard deviation is in parentheses.

Shoreline segment	<i>Rosa rugosa</i>				
	Mean colony length (m)	Mean colony width (m)	Mean colony height (cm)	Mean colony area (m ²)	Mean corrected colony area* (m ²)
A	2.8 (1.1)	2.0 (0.8)	81 (54.0)	6.4 (4.9)	6.1 (5.1)
B	4.1 (5.7)	3.1 (2.8)	104 (42.0)	22.7 (42.7)	9.3 (15.3)
D	8.1 (12.4)	3.2 (1.8)	118 (58.0)	40.1 (69.0)	39.9 (69.1)
F	6.2 (5.6)	4.0 (1.0)	109 (45.0)	28.1 (28.5)	28.1 (28.5)
G	10.7 (17.3)	4.3 (3.3)	119 (49.0)	69.5 (147.7)	48.1 (105.0)
H	5.4 (7.7)	3.3 (3.4)	74 (45.0)	35.4 (109.0)	21.7 (92.1)
J	5.4 (3.5)	2.0 (0.3)	151 (47.0)	10.7 (7.1)	10.4 (5.9)
J'	4.5 (2.9)	1.9 (0.3)	183 (27.0)	9.0 (5.9)	9.0 (5.9)

*Individual values represent colony area × cover value.

only scattered colonies of *Spiraea* shrubs and *Ribes* (currants and gooseberries), mostly toward the western end of the system. The bulk of the vegetation consisted of mixed forbs (including *Elymus* and *Ammophila*) and *Rubus* sp.

The 88 colonies mapped (Figure 2B) are an underestimate of the total number. Some extensive colonies had both pink and white flowers, suggesting that colonies had merged. This was more likely with pink-flowered colonies, as these outnumbered white-flowered colonies by at least 4:1. In addition, a few areas had hundreds of small shoots over an expanded area. These may have represented many individual plants, but for practical reasons these were considered as single colonies. Many apparently discrete colonies were also within a few metres of each other and thus may have been attached via rhizomes. The total area of the habitat with *R. rugosa* was 7100 m² (2723 m² when the percentage cover of the colonies is considered). These values represent 22.0% and 8.5% of the surface area of the sample space, respectively.

Colonies varied from roughly 0.4 m² to 2500 m² (maximum of 500 m² when area was corrected for cover), and from 0.3 to ca. 2.0 m in height. Mean colony area was 80.7 m² (SD 330). Colony size was highly skewed towards smaller clumps, with a median of 5.5 m². The two colonies with the largest overall areas were diffuse (15%–80% cover) and were away from the beachfront.

Of the 88 colonies, 29 (32.9%) were within 10 m of the top of the beach and are included in the perimeter calculation. These beachfront colonies were significantly taller (114 cm (SD 63) vs. 89 cm (SD 41), *P* = 0.025, Student *t*-test) than the remaining colonies on the beach.

Seed dispersal and seedling establishment

Processes that may have a bearing on the regeneration capability of *R. rugosa* were identified in the field, and some preliminary data were collected. On the western shore (shoreline segments G and H), many rose

hips had been stripped of their fleshy outside tissue. Direct observation of a Red Squirrel (*Tamiasciurus hudsonicus* Erxleben) holding up a rose hip next to a bush on the shoreline as well as the pattern of the stripping of the fruit from the outside of hips (consistent with Ebroch 2003), strongly suggested that squirrels might be affecting the dispersal of the rose hips. These hips were in various states of disintegration on the ground within a few metres of the putative parent plant (i.e., the nearest adult *R. rugosa*). Of the 124 scatters of seeds (in or out of remnant hip envelope) around 6 dispersing bushes at Lighthouse Cove, 47% consisted of 5 or fewer seeds, 20% had 6–10 seeds, and 19% had 11–20 seeds. In 14% of the seed scatters, most of the hip's seed complement was still retained (>50% of the average 33 seeds per hip). About 44% of the seed scatters were within 1 m (100 cm) of the parent bush and 66% were within 2 m (200 cm) (Figure 4A). The distribution of seed scatterings away from the parent bushes conforms best to an exponential curve (Figure 4A, exponential model *R*² = 0.89, linear model *R*² = 0.77).

At Peajack Cove, there was a high incidence of predation on the seeds that were scattered around the rose bushes. The frequency of predated (observed as gnawed holes in individual seed coats) seed among the scatterings of seed varied. The seed predator, though not identified, is hypothesized to be a small vole; the pattern of rose hip remains in deer mouse, *Peromyscus maniculatus* Wagner, middens (Ebroch 2003) suggests this animal also influences dispersal and regeneration of this invasive rose. There were many stripped hips in the turf around the bushes, and we examined the seeds from these hips to determine the number of intact vs. predated (i.e., seed contents consumed) seeds. Sixty-two hips from 6 bushes were surveyed, and 79% of these had either escaped predation (0–5% predation) or succumbed to predation (90–100% predation), leaving a minority with intermediate rates of seed predation.

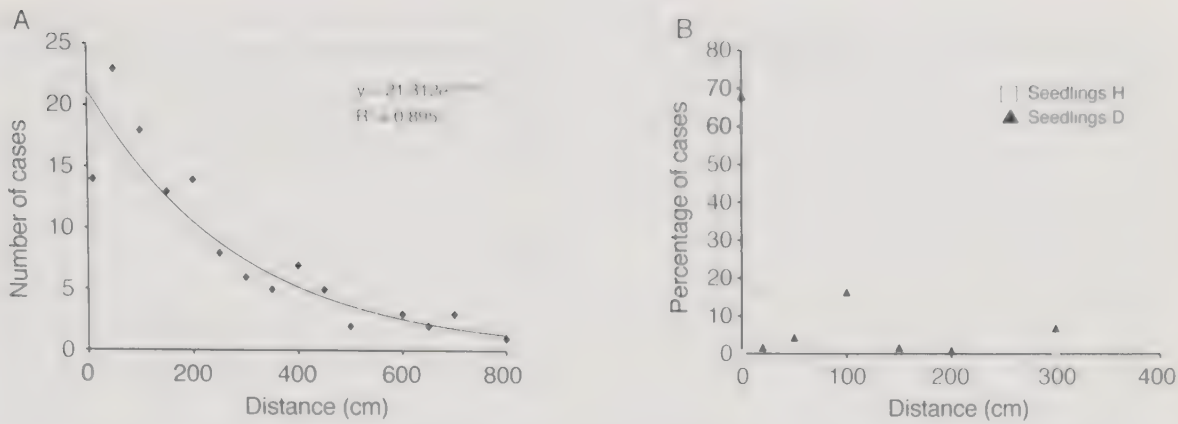


FIGURE 4. A. Distances of *Rosa rugosa* (Rugosa Rose) seed scatters (includes all cases in groupings ranging from an individual to a whole hip) from 6 bushes that were in various stages of frugivory at the start of shoreline segment G on Brier Island, Nova Scotia, in 2010. Note that data follow an exponential decay curve. B. The percentage of cases of seedlings of *R. rugosa* at various distances from parent colonies in shoreline segments D and H. Note that seedlings (e.g. at H) inside the margin of the parent bush are assigned to the zero distance class.

Seeds of *Rosa rugosa* were also observed among scats discovered along the coast during the search for seedlings and observations of dispersed hips. Of the 6 scats collected, 3 were from American Mink (*Neovison vison*, Schreber) and 3 belonged to a larger mammal, possibly a Coyote (*Canis latrans*, Say). From the mink scats, seed of Bayberry (*Morella pensylvanica*, (Mirb.) Kartesz, in 2 scats), blackberry (*Rubus* sp. in 2 scats), Black Crowberry (*Empetrum nigrum* L. in 1 scat), and *R. rugosa* (in 2 scats) were observed. Bayberry (in 2 scats), blackberry (1 scat) and *R. rugosa* (in 1 scat) were also observed in the larger mammal scat.

The frequency of colonies with associated seedlings (inspection conducted within 2 m of the margins of the parent bushes) was low (5%) in all shoreline segments, with the exception of segments D and H, where seedling occurrence frequencies (percentage of *R. rugosa* bushes with associated seedlings) were 55% and 25%, respectively.

Seedlings in segment D were established in sand at the margin of the parent clumps (Figure 4B). Although the average distance between seedlings and parents was 38 cm (SD 65) ($n = 116$), 63% of these seedlings were “nursed” under the margin of the parent bush. The average value is artificially inflated, since all cases of “nursing” were assigned a zero distance to the parent margin. Seedling density around 16 *R. rugosa* bushes examined, expressed as a function of bush area, gave a density of 1.8 seedlings per m² of area occupied by *R. rugosa* in this sand dune habitat.

In segment H, seedlings were not observed underneath parent plants (Figure 4B). The average distance between seedlings and parents was 69 cm (SD 27) ($n = 71$), approximately half the distance between the detached hips in this segment and the putative parents (124 cm, SD 121, $n = 102$). Seedlings in segment H were all associated with low biomass vegetation at the maritime/terrestrial transition; in all cases, seedlings

were associated with *Plantago maritima* (Seaside Plantain) and basaltic gravel.

The distribution of *R. rugosa* on Brier Island extends to areas that were surveyed for seedlings but which revealed very few (Figure 2A) (for 13 and 32 surveyed bushes in segments F and G, seedlings occurred at 0 and 6% of bushes, respectively). These segments did not have much of the two seedling nursery habitat types identified in segments D and H (*Ammophila breviligulata*, American Beachgrass) and sand in segment D and basalt gravel dominated by *P. maritima* in segment H). The non-wooded habitat of segments F and G was either more closed (e.g., old field turf of segment F) or the vegetation was more rank and vigorous (e.g., tops of cobble beaches and seeps in segment G). In these areas without natural seedling nurseries, there was an association between the existing clumps of *R. rugosa* and off-road vehicle trails (13% and 25% of *R. rugosa* clumps surveyed in segments F and G, respectively, were beside off-road vehicle trails) not noted in the other segments.

Discussion

Contrary to our expectations, the study results from Brier Island clearly dispute the garden infection model suggested for *Rosa rugosa* (Jørgensen and Kollmann 2009; Hill et al. 2010) and the classic account of *Berberis vulgaris* (Common Barberry) (Stakman et al. 1927). We found no evidence that *R. rugosa* gradually spread from Westport village around the coastline to surround the island. Indeed, in the two stretches of shoreline immediately adjacent to the village, *R. rugosa* was either absent (shoreline segment H) or had low density, with a large gap between the village and the first clump, i.e., 1.9 km (segment A). Furthermore, the occurrence of both pink- and white-flowered colonies scattered around the island suggests multiple colonizations based on stochastic events.

Jørgensen and Kollmann (2009) suggested that colonization of dunes in Europe was associated with roads and tracks. On Brier Island, the roadsides of the three main roads to the northern, western, and southern corners of the island were devoid of *R. rugosa* for distances of over 1, 2, and 3 km from the respective shores. Hence colonization from the community via gradual spread along these routes is regarded as unlikely.

Having falsified our original hypothesis, we suggest two alternate hypotheses to explain how *R. rugosa* dispersed from the village to distant shorelines around Brier Island: animal vectors and water dispersal mediated by tides, waves, and currents.

Once colonization of the western shore had occurred (i.e., reached segments G and H), we suggest that off-road vehicles provided a dispersal mechanism by trapping and transporting seeds within the coarse treads of tires. We have no experimental data to support this, but the densest clumps on Brier Island (other than in segment D) were adjacent to seaside trails primarily used by off-road vehicles (e.g., segments G and H). Where these trails departed from an immediate seaside path, colony density was greatly reduced (i.e., segment F).

Rosa rugosa was introduced to Nova Scotia as an ornamental shrub in residential areas. By the 1920s, this species had become naturalized, and Fernald (1921) reported it as common in Yarmouth County. We have no formal record of the introduction of the species on Brier Island, but Westport has numerous small plantings and hedges around dwellings that are likely of long standing. These likely were the source of the wild populations described in this paper. The large number of small plants and the absence of conspicuous dead plants are consistent with an ongoing colonization facilitated by large colonies with their attendant fecundity. The observations of the establishment of seedlings suggest that mass colonization of the shorelines is underway.

Regional climate change and sea level rise may be facilitating the spread of *R. rugosa*. While all seaside plants must have some salt tolerance, *R. rugosa* is particularly salt tolerant (e.g., Dirr 1978). This was evident on Brier Island, where colonies were also present in the cobble at the tops of beaches, even closer to the sea than other shrub species. Once *R. rugosa* becomes established, its greater height and dense shoots allow it to exclude other shrubs. On sand dunes, *R. rugosa* may colonize the dune slacks (e.g., Hill *et al.* 2010), but *R. rugosa* is typically on the seaward side of its congener, the native *R. virginiana*.

While dispersal of *R. rugosa* by birds has been observed elsewhere in offshore islands in the Bay of Fundy (Rajakaruna *et al.* 2009) and birds are a likely vector on Brier Island which has a large population of Herring Gulls (*Larus argentatus*, Pontoppidan), we have evidence that a suite of native mammals effect and affect the dispersal of this invasive rose. From scat dissection, we know that two mammals, the American

Mink and a larger animal (possibly a Coyote), ingest the fleshy rose hip tissue and whole seeds. The Red Squirrel, in contrast, removes the hips from bushes, strips the fruit from the hip, consuming the fruit, and then discards the stripped hip. Finally, these stripped, discarded hips are predated—in *situ* it would appear—at an unknown final efficiency rate, by a small rodent, possibly by Deer Mice (see Ebroch 2003).

Rose hips that are consumed by American Mink would be dispersed away from the source bush but would likely remain in the headland habitat. American Mink have been documented as a major consumer of another seaside fruit, *Empetrum nigrum* L. (Black Crowberry) (Hill *et al.* 2012), whose fruit matures much earlier than *Rosa*. The island has had a population of Coyotes since the 1980s and fruit can make up a large part of their diet (Quinn 1997). This putative disperser would tend to deposit scats along the same paths and trails (see Dodge and Kashian 2013) that are frequented by the off-road vehicle. In contrast, there appears to be no endozoochory of *Rosa* seed taken by the Red Squirrel. All the scattered rose hips dispersed in segments G and H had the fleshy fruit stripped from the hip. Some of the hips still attached to the bushes showed selective eating of the fleshy part of the fruit and avoidance of the seeds. A Red Squirrel with a stripped hip in its paws was observed in segment G by NMH, consistent with the distribution of seeds scattered around parent bushes along the western shore of Brier Island (i.e., data from segment H). We suspect that dispersal of *Rosa* by Red Squirrels is the first stage leading to secondary dispersal processes that may be as significant as the primary dispersal process. We documented variation in the percentage of seeds that were predated by a secondary disperser whose activity fits the known pattern of rose hip utilization by the Deer Mouse (Ebroch 2003). It is likely that much of the mechanical disruption of discarded hips is brought about by this seed predator. We do not yet understand the interaction between the primary disperser (Red Squirrel) and this seed predator. The seed dispersal shadow generated by the Red Squirrel was fitted by a negative exponential regression, however, this curve has a short tail and seed scatters were not found more than 8 metres from the parent bush. Documenting how the secondary disperser might extend the tail of this seed shadow (see Nathan and Muller-Landau 2000) in this invasive rose would advance our understanding of the *Rosa rugosa* colonization and invasion mechanism.

At the population level, there are advantages to a scatter of seed. In some cases, all seeds in a small group will be consumed or will germinate in unsuitable substrate; in other cases, a few escape consumption and are brought to a good seed bed. Such a seed bed could be the unvegetated muddy flat of an off-road vehicle trail. We noted in segments F and G that natural seedling nurseries were rare, but that *R. rugosa* bushes had

a strong association with off-road vehicle trails. Could off-road vehicles be causing the requisite disturbance to allow for seedlings to become established in old fields and in rank vegetation? It is conceivable that, once off-road vehicle trails have been established, off-road vehicles are the dispersal agents for the next generation of seedlings.

Given the concerns about the secondary dispersal role played by farm machinery and other vehicles in the spread of weeds and invasive exotic species (Clifford 1959; Lonsdale and Lane 1994; Garnier et al. 2008), we should be investigating this potential in the off-road vehicle. These vehicles frequently create disturbed seed beds in otherwise closed vegetation throughout North America. Logically, they must also move a fraction of the soils and propagules that they disturb.

On Brier Island, the population of *R. rugosa* has expanded as a result of both natural and anthropogenic factors. This exotic plant meets a strict definition of an invasive plant as “an exotic species regenerating in the wild in sufficient numbers to influence the dynamics of native plant communities” (Hill and Blaney 2010). Hence it is more than merely a reflection of the anthropogenic disturbance footprint (e.g., Jenkins and Pimm 2003). The population on Brier Island has native seed dispersers that deliver it to seedling regeneration niches in native habitats (sand in American Beachgrass dune, gravel in seashore Seaside Plantain zone), where natural disturbances maintain a supply of gaps where seedlings can become established. In the absence of anthropogenic activity, seedlings would continue to sprout on sand dunes, nursed by or in the lee of adult bushes, and in crumbling basalt at the terrestrial/marine interface. These areas could become the realized niche of *R. rugosa* in the absence of anthropogenic process and disturbance. In the meantime, we suggest that a mixture of human and natural processes and disturbance will continue to encourage the spread of this invasive.

Given the current state of colonization of Brier Island, it is easy to raise the spectre of virtually the entire island being ringed by *R. rugosa*. We observed no evidence of dieback or either landscape or competitive interactions that would constrain further growth. Other than areas where wetlands, dense Green Alder shrubbery or coniferous woodland occurred at the limits of terrestrial vegetation along the shore, or in areas of cliffs, all substrate and vegetation types were colonized by *R. rugosa*.

Kollmann et al. (2009) showed a clonal spread rate of 0.42 m year^{-1} on coastal dunes in Europe. This is the equivalent of one successful shoot per clone based on rhizome spread and emergence of a new shoot. The growth rate that we determined in one large colony on exposed heathland was 0.65 m year^{-1} over a 21-year period. The higher growth rate projected over 9 years in segment D of 2.3 m year^{-1} may be an exaggeration

because of the lack of competition from other woody plants in the beach habitat.

Relative to our data, the growth rate of 0.42 m year^{-1} observed by Kollmann et al. (2009) provides a conservative estimate for modeling colony spread. Accordingly, the 300 coastal colonies that we mapped would produce an extension of colony length parallel to the shore of about 120 m year^{-1} from existing colonies. Extrapolating this rate to 2020 results in an increase of 1200 m that would encompass 16% of the island perimeter. This is without the addition of new colonies. If new colonies become established at 5% per year (i.e., 15 new colonies in 2011), after 10 years the island would have almost 500 colonies, and these colonies would have resulted in an additional 400 m of the perimeter being occupied by *R. rugosa*. Accordingly, by 2020, 18% of the island perimeter would be occupied by *R. rugosa*. Since most colonies are concentrated in about two-thirds of the island, this would represent a dramatic change in the coastal vegetation on the shores facing the Bay of Fundy. An exponential modeling of colony increase would result in even more dramatic changes.

Brier Island is representative of the coastline of much of Nova Scotia. This is particularly true of the headlands of the numerous peninsulas of Nova Scotia that extend into the Atlantic Ocean and the numerous offshore islands along the Atlantic coast (e.g., Hill et al. 2012). Consequently, we conclude that *R. rugosa* represents a serious threat to native plant communities on windswept coastal headlands and offshore islands of the region. We encountered a diversity of native herbs and shrubs, including those that are uncommon and of small stature (e.g., Knotted Pearlwort, *Sagina nodosa*, (L.) Fenzl. and Roseroot, *Rhodiola rosea* L.) along the coast of Brier Island. In contrast, we consistently have observed a dearth of diversity under the bushes of *R. rugosa*. This exotic rose is so abundant that it has become part of the economic botany (for jams and wine) of this area; clearly, there is a need to assess its impact on coastal biodiversity.

Bruun (2006) outlined potential strategies for biological control for *R. rugosa*, and biological control must be considered as a potential option to limit the spread of the species and its impact on native biota. Hill et al. (2012) suggested a series of management strategies for the preservation of coastal *Empetrum nigrum* L. heathlands. Management of *R. rugosa* may become a critical part of this strategy.

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Notes

New and Noteworthy Records of Orthoptera and Allies in the Maritimes and the Îles-de-la-Madeleine, Quebec

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Chortophaga viridifasciata, *Forficula auricularia*, *Melanoplus stonei*, *Scudderella furcata furcata*, *Scudderella pistillata*, and *Trimerotropis verruculata* from Prince Edward Island and *Doru taeniatum*, *Melanoplus punctulatus*, *Orchelimum gladiator*, and *Spharagemon bolli* from New Brunswick are new provincial records. Other records of interest include the endemic *Melanoplus madeleineae* from Île d'Entrée in the Îles-de-la-Madeleine, Quebec; *Trimerotropis verruculata* from the Îles-de-la-Madeleine, Quebec; and *Chortophaga viridifasciata*, *Stethophyma lineatum*, and *Tetrix subulata*, new for Cape Breton Island, Nova Scotia. The ranges of *Conocephalus brevipennis*, *Tetrix arenosa angusta*, *Tetrix ornata*, and *Tetrix subulata* are significantly extended in New Brunswick. A previously unpublished record from 2003 of *Roeseliana roeselii* (*Metrioptera roeselii*) is the earliest report of this European introduction to the Maritimes.

Key Words: *Chortophaga viridifasciata*; *Conocephalus brevipennis*; *Doru taeniatum*; *Forficula auricularia*; *Melanoplus madeleineae*; *Melanoplus punctulatus*; *Melanoplus stonei*; *Metrioptera roeselii*; *Orchelimum gladiator*; *Roeseliana roeselii*; *Scudderella furcata*; *Scudderella pistillata*; *Spharagemon bolli*; *Stethophyma lineatum*; *Tetrix arenosa*; *Tetrix ornata*; *Tetrix subulata*; *Trimerotropis verruculata*; new records; Île d'Entrée; Îles-de-la-Madeleine; Quebec; Maritimes; New Brunswick; Prince Edward Island; Nova Scotia; Cape Breton Island

Since the classic works of Vickery *et al.* (1974), Kevan and Vickery (1977), Vickery and Kevan (1985), and Vickery and Scudder (1987), there have been a number of new records of Orthoptera and allies in various parts of the Maritimes (New Brunswick, Nova Scotia, and Prince Edward Island) and Quebec, including *Metrioptera roeselii* (Hagenbach), reported by McAlpine (2009) from New Brunswick, and *Neoconocephalus retusus*, reported by Catling *et al.* (2009) from Sable Island, Nova Scotia. Newly reported by Scudder and Vickery (2010) are *Periplaneta brunnea* Burmeister established in Nova Scotia; *Supella longipalpa* (Fabricius), established in Nova Scotia; and *Oecanthus nigricornis* F. Walker, in New Brunswick. The report of *Allonemobius maculatus* (Blatchley) by Scudder and Vickery (2010) is thought to be an error, since we know of no records for this species from the Maritimes or Quebec. Chandler (1992) reported the Dusky Cockroach, *Ectobius lapponicus* (L.), for the first time in Canada from Prince Edward Island. McAlpine and Ogden (2012) reported *Conocephalus brevipennis* (Scud-

der) new to New Brunswick and the Maritimes, *Orchelimum gladiator* Bruner new to Prince Edward Island and the Maritimes, *Neonemobius palustris* (Blatchley) new to New Brunswick, *Oecanthus nigricornis* F. Walker new to Nova Scotia, and *Stethophyma lineatum* (Scudder) new to New Brunswick.

During 2008–2012, additional new provincial occurrences and other notable range extensions for Orthoptera and allies were recorded, either in the course of field work in the Maritimes and the Îles-de-la-Madeleine, Quebec, or during the examination of collections. New provincial occurrences or other notable range extensions within provinces, including particularly Cape Breton Island (Nova Scotia) and the Îles-de-la-Madeleine (Quebec), are listed alphabetically by species below. The nomenclature follows Orthoptera Species Online (Eades *et al.* 2013) as well as Vickery and Kevan (1985). Most identifications were made using the latter. Voucher specimens are deposited in the Canadian National Collection of Insects at Agriculture and Agri-Food Canada in Ottawa; the University of Prince Edward

Island in Charlottetown; the Charlottetown Research Station, Agriculture and Agri-Food Canada, Charlottetown; and the New Brunswick Museum in Saint John.

New provincial records

DERMAPTERA

New Brunswick

Doru taeniatum (Dohrn)

Prince Edward Island

Forficula auricularia Linnaeus

ORTHOPTERA

New Brunswick

Melanoplus punctulatus punctulatus (Scudder)

Orchelimum gladiator Bruner

Spharagemon bolli Scudder

Prince Edward Island

Chortophaga viridifasciata De Geer

Melanoplus stonei Rehn

Scudderella furcata furcata Brunner von Wattenwyl

Scudderella pistillata Brunner von Wattenwyl

Trimerotropis verruculata (Kirby)

Other noteworthy records

New Brunswick

Conocephalus brevipennis (Scudder)

Roeseliana roeselii (Hagenbach)

Tetrix arenosa angusta Hancock

Tetrix ornata (Say)

Tetrix subulata (Linnaeus)

Îles-de-la-Madeleine, Quebec

Melanoplus madeleineae Vickery and Kevan

Trimerotropis verruculata (Kirby)

Cape Breton Island, Nova Scotia

Chortophaga viridifasciata De Geer

Stethophyma lineatum (Scudder)

Tetrix subulata (Linnaeus)

New provincial records

DERMAPTERA

Doru taeniatum (Dohrn)—NEW BRUNSWICK: Saint John, Saint John Co., 45.2509, -66.1012, 13 November 2010, vegetable produce originating in Mexico, *D. Malloch* (New Brunswick Museum).

Two live specimens were retrieved from bagged celery originating in Mexico in a local grocery chain. The species is not known to be established in the Maritimes but it is established in southern Michigan, where it occurs in *Carex lacustris* marshes (Vickery and Kevan 1985). *Doru taeniatum* has a widespread distribution in the Americas and is easily recognized by the yellowish stripes on the wing covers (Brindle 1971).

Forficula auricularia L.—PRINCE EDWARD ISLAND: Charlottetown, Queens Co., 46.2333, -63.1333, 13

September 1979, *M.M. Smith* (Agriculture and Agri-Food Canada, Charlottetown); Charlottetown, Queens Co., 46.2333, -63.1333, 12 August 1981, *L. S. Thompson* (Agriculture and Agri-Food Canada, Charlottetown); Holiday Haven, Cornwall, Queens Co., 46.2277, -63.2182, 15 July 1982, *L. S. Thompson* (Agriculture and Agri-Food Canada, Charlottetown); Marshfield, Queens Co., 46.3, -63.0833, 9 September 1983, *L. S. Thompson* (Agriculture and Agri-Food Canada, Charlottetown); Marshfield, Queens Co., dry slope beside graveyard, 46.3086, -63.0503, 19 September 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Covehead Road, Route 25, 1 km N of Route 220 junction, under building refuse, 46.35344, -63.11322, 4 October 2010, *D. F. McAlpine* (New Brunswick Museum); Charlottetown, Queens Co., under rotted wood, 46.240, -63.135, 5 October 2010, *D. F. McAlpine* (New Brunswick Museum); Bonshaw, Queens Co., 7 May 2011, *P. M. Catling* (Canadian National Collection of Insects); Kensington, Prince Co., under rotted wood, 46.42916, -63.65323, 12 August 2011, *D. F. McAlpine* (New Brunswick Museum).

Based on specimens cited above (which are at the Charlottetown Agriculture and Agri-Food Canada Research Station and the New Brunswick Museum), this species was introduced onto Prince Edward Island in the late 1970s and is now well established.

ORTHOPTERA

Chortophaga viridifasciata De Geer—PRINCE EDWARD ISLAND: 2.7 km NNE of Caledonia, Kings Co., nymph 1.2 cm long in open sandy area surrounded by shrubby thickets, 46.0819, -62.6953, 20 August 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Shaw Road and Dundas Road, 1.7 km east of Albion, Kings Co., nymph 1.2 cm long, dry open *Danthonia spicata* at edge of blueberry field, 46.34037, -62.46646, 7 May 2011, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects).

NOVA SCOTIA, CAPE BRETON ISLAND: Ingonish Centre ball field, Ingonish, Victoria Co., 46.66598, -60.40795, 2 September 2009, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects).

This species overwinters as a nymph. The adults are developed by late May, making it the first grasshopper of the year to appear as an adult. Sometimes during a winter thaw, the nymphs will become active and hop around over melting snow. All new records above are of late summer or spring nymphs.

Melanoplus punctulatus punctulatus (Scudder)—NEW BRUNSWICK: New Brunswick-Quebec border along Route 2, 16.7 km NNW of Edmundston, Madawaska Co., *Picea mariana* forest with scattered *Pinus strobus*, 47.48691, -68.48336, 22 July 2011, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Fredericton (Nashwaaksis), York Co., sidewalk adjacent to small area of mixed woods including *Pinus*

resinosa and *Pinus strobus*, 45.98550 –66.64663, 14 September 2012, A.W. Thomas (New Brunswick Museum) (Figure 1).

Usually feeding on pine (*Pinus* spp.) foliage, this species occurs commonly on trunks late in the season. It was previously recorded in Quebec within 100 km of the border of northwestern New Brunswick (Vickery and Kevan 1985). Although it is known from the Montreal region and northward, *Melanoplus punctulatus punctulatus* has not been found previously in the Atlantic Maritime Ecozone (Scudder and Vickery 2010), which includes the eastern townships of Quebec. The new records for New Brunswick are the easternmost.

Melanoplus stonei Rehn— PRINCE EDWARD ISLAND: Prince Edward Island National Park of Canada, Kings Co., open dunes, 51.06974, –114.094580, 19 August 2008, P. M. Catling (Canadian National Collection of Insects).

Pale specimens referable to this species were found on the open dunes with only American Beachgrass (*Ammophila breviligulata*) in Prince Edward Island National Park of Canada near Greenwich on 19 August 2008. They occurred in the same open sandy habitat as pale grey specimens of *Dissosteira carolina*. *Melanoplus stonei* is found in the Great Lakes region and southern Manitoba, becoming rare and isolated eastward to New Brunswick and now Prince Edward Island. The distribution suggests that it may be an early postglacial relict dating from a time approximately 10 000 years ago, when open sandy habitat was more widespread in the *Picea* parklands near the front of the continental glacier.

Orchelimum gladiator Bruner— NEW BRUNSWICK: Callendars Beach, Kouchibouguac National Park of Canada, Kent Co., grass–shrub border adjacent to coast, 46.80732, –64.90716, 18 July 2012, A. Martin and D. Doucet (New Brunswick Museum) (Figure 2); Wilkins Field, Fredericton, York Co., wet meadow, 45.97592, –66.67515, 28 July 2012, G. Belliveau (New Brunswick Museum); Carleton Park, Fredericton, York

Co., tall grasses along Saint John River, 45.96077, –66.62690, 23 August 2012, G. Belliveau (New Brunswick Museum).

McAlpine and Ogden (2012) recorded this species from the Maritimes for the first time (on Prince Edward Island) and suggested it should be widespread in the region. Records above from New Brunswick support this assessment. Perhaps the species is a recent arrival to the region, since it was not recorded during intensive insect surveys carried out in 1977–1978 in Kouchibouguac National Park of Canada by Agriculture Canada entomologists (Miller and Lyons 1979*).

Scudderella furcata furcata Brunner von Wattenwyl— PRINCE EDWARD ISLAND: near Cherry Hill [Kings Co.], shrubby area beside swamp, 46.3826, –62.8605, 19 September 2008, P. M. Catling and B. Kostiuik (Canadian National Collection of Insects); N of Wood Island, Highway 4, shrubby roadside, 45.967, –62.7328, 18 September 2008, P. M. Catling and B. Kostiuik (Canadian National Collection of Insects); N of Wood Island [Queens Co.], Highway 4, leatherleaf bog, 45.9673, –62.729, 18 September 2008, P. M. Catling and B. Kostiuik (Canadian National Collection of Insects).

Previously known in the Maritimes from Cape Breton Island (Nova Scotia) and mainland Nova Scotia.

Scudderella pistillata Brunner von Wattenwyl— PRINCE EDWARD ISLAND: Flat River [Queens Co.], 46.0071, –62.8575, 2 September 1953, J. White (University of Prince Edward Island); Cardigan [Kings Co.], 46.2331, –62.6187, 27 September 1953, F. McLeod (University of Prince Edward Island); Belmont [Prince Co.], 46.4832, –63.8163, 30 September 1956 (University of Prince Edward Island); St. Eleanors [Prince Co.], ECB pheromone trap, 46.4166, –63.8166, 11 August 1988, J. G. Stewart (Charlottetown Research Station, Agriculture and Agri-Food Canada); Southside, ECB pheromone trap, 23 August 1990, M. E. M. Smith



FIGURE 1. *Melanoplus punctulatus punctulatus*, Fredericton (Nashwaaksis), York County, New Brunswick, 14 September 2012, a species associated with pines. Photo: A. W. Thomas.



FIGURE 2. *Orchelimum gladiator*, Callendars Beach, Kouchibouguac National Park of Canada, Kent County, New Brunswick, netted by Park visitor A. Martin on 18 July 2012 during a public “bioblitz” organized by the Park. Photo: D. Doucet.

(Charlottetown Research Station, Agriculture and Agri-Food Canada); Blooming Point [Queens Co.], 46.4052, -62.9598, 23 July 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Driftwood Cottages near Tignish [Prince Co.], 25 July 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); near Burnt Point [Kings Co.], saltmarsh, 46.17922, -62.51176, 27 July 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Highway 113, Cardigan Road, 46.29538, -62.62018, 10 August 2009, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects).

Previously known from New Brunswick and from Cape Breton Island (Nova Scotia) and mainland Nova Scotia.

Spharagemon bolli Scudder—NEW BRUNSWICK: 2 km W of St. George, Charlotte Co., open rock on open hilltop dominated by blueberry, 45.13682, -66.85981, 9 August 2009, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects).

Previously known from southwestern Maine and Quebec adjacent to northwestern New Brunswick (Vickery and Kevan 1985), this species was found in open rock and gravel on an open hilltop dominated by blueberry.

Trimerotropis verruculata (Kirby)—PRINCE EDWARD ISLAND: Highway 12 W, clearcut beside old sand pit, 4 km S of Doyle Road, 46.968, -64.0055, 25 July 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); open shrubby areas of back dunes at Cedar Dunes Provincial Park, West Point [Prince Co.], 46.6201, -64.38615, 26 July 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Georgetown [Kings Co.] lumber yard, 46.19252, -62.53757, 27 July 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Wood Islands ferry [Queens Co.], edge of parking lot, 45.95481, -62.74798, 27 July 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Murray Road, dry sandy area with blueberry, 45.9821, -62.7176, 18 September 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Little Harbour [Kings Co.], Road 303, sand pit, 46.3677, -62.189, 19 September 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); near Glencorradale [Kings Co.], two-year-old clearcut, 46.413, -62.2285, 20 September 2008, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects).

QUEBEC, ÎLES-DE-LA-MADELEINE: Îles de la Madeleine, ferry terminal, Cap-aux-Meules, 47.38259, -61.8589, 12 August 2009, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Îles de la Madeleine, Cap-aux-Meules pit, 47.36505, -61.91158, 14 August 2009, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Îles de la Madeleine, Butte de la Croix, 47.23705, -61.85708, 14 August 2009, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Îles de la Madeleine, Havre-Aubert, chemin du Sable, 47.22147, -61.0321, 14

August 2009, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Île du Havre aux Maisons, open, dry, sandy heathland beside airport, *Empetrum* dominant, 47.42017, -61.78595, 11 August 2010, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Île du Havre aux Maisons, Butte sur Mer, open rocky hilltop, *Danthonia* dominant, 47.39261, -61.77411, 11 August 2010, *P. M. Catling and B. Kostiuk* (Canadian National Collection of Insects); Île d'Entrée, sandy and stony beach at dock, 47.27683, -61.71788, 14 August 2010.

This species was expected but likely overlooked previously on Prince Edward Island. This may have been due to the limited habitat available. Habitat includes open gravelly or sandy areas and exposed substrate of burns, where the species is active and conspicuous only in warm, sunny weather. Although *Trimerotropis verruculata* is found in several places in the Îles-de-la-Madeleine, there is a possibility that it has recently been introduced there, since it was not recorded in an earlier survey (Kevan and Vickery 1977) and its crepitation can be heard over a distance of almost 1 km. It is hard to imagine that Kevan and Vickery missed it.

Other noteworthy Orthoptera records

Conocephalus brevipennis (Scudder)—NEW BRUNSWICK: Douglas, York Co., grassy ditch along road, 45.99985, -66.7644, 7 October 2012, *D. L. Sabine* (New Brunswick Museum).

McAlpine and Ogden (2012) reported this species from the Maritimes for the first time, based on specimens collected in Queens County, New Brunswick, in 2008 and 2011. They suggested that the species had previously been overlooked but that records were too few to assess distribution or status. Here we add York County to the New Brunswick distribution. Our knowledge of the status of this species in the Maritimes remains scanty.

Roeseliana roeselii (Hagenbach)—NEW BRUNSWICK: eastern end of Princess Margaret Bridge, Fredericton, York Co., periodically mowed right-of-way, 45.94316, -66.61769, 19 July 2003, *D. L. Sabine* (New Brunswick Museum); Fredericton, York Co., approximately 45.92, -66.64, 15 July 2006, *C. Adam* (Figure 3, photo



FIGURE 3. A photo record of *Roeseliana roeselii* taken at Fredericton, York County, New Brunswick, on 15 July 2006 that pre-dates the previous first published report in McAlpine (2009). See text for a still earlier record. Photo: C. Adam.

only); approximately 4.5 km NW of Riverside-Albert, Caledonia Gorge Protected Natural Area, Albert Co., 45.77734 –64.78674 and 45.77267 –64.78485, 20 and 21 August 2012, old-field habitat, open woods road verge, A. A. D. Fairweather, D. F. McAlpine (New Brunswick Museum).

This species, called *Metrioptera roeselii* by Vickery and Kevan (1985), is evidently very well established in New Brunswick, having been previously reported in Charlotte, Saint John, Queens, and Kent counties (McAlpine 2009; McAlpine and Ogden 2012). Here we add Albert County, in the Caledonia Gorge Protected Natural Area, and York County. Although this species was previously first recorded in the Maritimes in 2009, specimen and photo records included here from 2003 and 2006, combined with the rapid accumulation of records supporting a wide distribution in the province, suggest that *R. roeselii* was probably present in the Maritimes well before 2003. Based on collections from the Caledonia Gorge Protected Natural Area, this species will readily colonize old-field habitat even in areas otherwise heavily forested.

Melanoplus madeleineae Vickery and Kevan—QUEBEC, ÎLES-DE-LA-MADELEINE: Île du Havre aux Maisons, northeast corner, *Carex–Juncus–Eupatorium* wetland among hills overlooking Dune du Sud and Île d'Entrée, 47.4069, –61.765, 11 August 2010, P. M. Catling and B. Kostiuk (Canadian National Collection of Insects) (Figure 4); Île du Havre aux Maisons, hill-slope on Butte Ronde, dead on the road, 47.39495, –61.77286, 13 August 2010, P. M. Catling and B. Kostiuk (Canadian National Collection of Insects); Île d'Entrée, start of path to Big Hill, open acidic rocks and

path edge, stepped on by hiker, 47.27649, –61.70073, 14 August 2010, P. M. Catling and B. Kostiuk (Canadian National Collection of Insects).

Any records of this uncommon and evidently taxonomically acceptable (Chapco and Litzenberger 2002) endemic (not to be confused with *M. magdalenae* of the Magdalena Mountains of New Mexico) are of interest. Previously it was found only on islands of the main chain of the Îles-de-la-Madeleine. Île d'Entrée is separated from the rest of the group by 4.8 km of ocean. In 2009 and 2010, only three females were found (listed above) from a search of more than 50 localities (separated by 1 km) throughout the islands, including Île Brion. Although the surveys were conducted in August when this possibly early grasshopper might have occurred in decreased numbers, there is also a possibility that it has declined due to habitat loss, increased traffic on roads and paths, and predation by introduced [European] Starlings [(*Sturnus vulgaris*)]. Flocks of [European] Starlings are abundant, and they are efficient predators of grasshoppers on the islands (P. M. Catling, personal observation). Remains of *M. madeleineae* were found in regurgitated pellets of Whimbrel [(*Numenius phaeopus*)] on Grosse Île.

Stethophyma lineatum (Scudder)—NOVA SCOTIA, CAPE BRETON ISLAND: 15 km NE of Baddeck [Victoria Co.], marshy ditch, 5 September 2009, P. M. Catling and B. Kostiuk (Canadian National Collection of Insects).

Since it was already known from mainland Nova Scotia, Prince Edward Island, and the island of Newfoundland in Newfoundland and Labrador, the occurrence of *Stethophyma lineatum* on Cape Breton Island (Nova Scotia) was anticipated. McAlpine and Ogden (2012) recently reported this species for the first time at two localities in New Brunswick, but overlooked an earlier unpublished report from Kouchibouguac National Park (Miller and Lyons 1979*).

Tetrix arenosa angusta, Hancock—NEW BRUNSWICK: Grand Bay-Westfield, Kings Co., sparsely vegetated ground, 45.3406, –66.2539, 8 September 2008, D. F. McAlpine (New Brunswick Museum).

Known previously in New Brunswick from a single record from York County (probably Fredericton) (Vickery and Kevan 1985).

Tetrix ornata (Say)—NEW BRUNSWICK: Menneval, Restigouche Co., 47.80747, –67.17541, 17 June 1964, G. G. E. Scudder (Canadian National Collection of Insects); Saint John, 45.27, –66.07, Saint John Co., 4 June 1899, W. McIntosh (New Brunswick Museum); Saint John, approximately 45.27, –66.07, Saint John Co., 9 June 1901, W. McIntosh (New Brunswick Museum) Crooked Creek bridge, Caledonia Gorge Protected Natural Area, vegetated roadside, 45.79684, –64.77653, A. A. D. Fairweather (New Brunswick Museum, no date).

Vickery and Kevan (1985) map a single record for this species, from northwestern New Brunswick in the Kent–Northumberland counties border region. Historical collections in the New Brunswick Museum and the Canadian National Collection of Insects and a recent collection from the Caledonia Gorge Protected Natural Area add Restigouche County, Saint John County, and Albert County, together suggesting a wide distribution in the province.



FIGURE 4. *Melanoplus madeleineae*. Above, open meadow habitat on Île du Havre aux Maisons in the Îles-de-la-Madeleine, Quebec, with Île d'Entrée in the background on 11 August 2010. Below, female *Melanoplus madeleineae* on 11 August 2010. Photos: P. M. Catling.

Tetrix subulata (Linnaeus)—NEW BRUNSWICK: Saint John, 45.27, -66.07, Saint John Co., 2 June 1898, *W. McIntosh* (New Brunswick Museum); Saint John, 45.27, -66.07, Saint John Co., 1 May 1899, *W. McIntosh* (New Brunswick Museum).

NOVA SCOTIA, CAPE BRETON ISLAND: an old sand pit at South Harbour [Victoria Co.], 46.86618, -60.46291, 2 September 2009, *P. M. Catling* and *B. Kostiuk* (Canadian National Collection of Insects).

Vickery and Kevan (1985) map this species from various localities in western New Brunswick and the extreme north-eastern corner of the province. The historical records below appear to be the first from Saint John County and confirm a widespread distribution for this species in New Brunswick, at least historically. Considering the widespread distribution of the species in the Maritimes generally (Vickery and Kevan 1985), the presence of *T. subulata* on Cape Breton Island, Nova Scotia, was expected.

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Isotopic Evidence of Salmon, *Oncorhynchus* spp., in the Diet of the Wolverine, *Gulo gulo*, on Princess Royal Island, British Columbia

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Shardlow, Thomas F. 2013. Isotopic evidence of salmon, *Oncorhynchus* spp., in the diet of the Wolverine, *Gulo gulo*, on Princess Royal Island, British Columbia. *Canadian Field-Naturalist* 127(4): 338–342.

Evidence from $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope signatures from hair samples from a Wolverine, *Gulo gulo*, suggest the use of salmon, *Oncorhynchus* spp., in the diet of the Wolverine on Princess Royal Island on the north coast of British Columbia. This is also the first published record of Wolverines on that island.

Key Words: Wolverine; *Gulo gulo*; salmon; *Oncorhynchus* spp.; isotope; carbon-13; $\delta^{13}\text{C}$; nitrogen-15; $\delta^{15}\text{N}$; Princess Royal Island; British Columbia; camera station

Introduction

The Wolverine (*Gulo gulo*), the largest of the terrestrial mustelids, has a circumpolar distribution favouring northern latitudes and high elevations (Hatler *et al.* 2008). Wolverines are widely distributed in British Columbia, with an affinity for interior and snowy habitats. Wolverines are considered rare on the coast (Lofroth and Krebs 2007); however, they have been recorded in some coastal areas, such as Vancouver Island.

Wolverines found in coastal watersheds of British Columbia would be expected to encounter moribund salmon (*Oncorhynchus* spp.) from spawning runs in many of the streams. However, there are no records of salmon consumption by this scavenger. Wolverine diets have been reported as exclusively derived from terrestrial vertebrates (Magoun 1987; Lofroth *et al.* 2007; Dalerum *et al.* 2009), even in studies conducted in areas where spawning salmon were present.

This note presents evidence from carbon-13 isotopes ($\delta^{13}\text{C}$) and nitrogen-15 isotopes ($\delta^{15}\text{N}$) taken from Wolverine hair samples that suggest that salmon is present in the diet of a Wolverine on Princess Royal Island on the north coast of British Columbia. It is also the first published record of Wolverines on this island.

Methods

Study area and field sampling

Seventeen camera stations located in riparian and surrounding low-elevation habitats were established along Chapple Inlet on Princess Royal Island (Figure 1) during a study to monitor scavengers and predators of salmon (*Oncorhynchus* spp.) in riparian ecosystems (Shardlow 2013; Shardlow and Hyatt 2013).

Princess Royal Island (2250 km²) is the largest island on the north coast of British Columbia, and it remains mostly as mature forest. Chapple and Douglas creeks flow into the head of Chapple Inlet on the west side of the island. Pink Salmon (*Oncorhynchus gorbuscha*) are the predominant spawners, along with small numbers of Chum Salmon (*O. keta*) (DFO, 2013). Many small

streams in the vicinity also support salmon. Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*), Blue Grouse (*Dendragapus obscurus*), American Beaver (*Castor canadensis*), and Douglas' Squirrel (*Tamiasciurus douglassii*) were among some of the Wolverine's potential prey items recorded by the cameras during the study.

Wolverine sightings were recorded using a motion-activated infrared digital camera (PC-85 from Reconyx, Holmen, Wisconsin, USA) at each of the 17 trapping stations. Sampling techniques followed the methods detailed by Shardlow and Hyatt (2013). Untreated organic fish fertilizer was used as the primary scent lure. The fertilizer was poured onto the ground inside a barbed-wire "enclosure" used to snag hair samples. Additional scent lures (from Wildlife Control Supplies Ltd., East Granby, CT, USA), designed to attract a wide variety of predators and scavengers, were also placed inside the enclosures (e.g., beaver castor, anchovy extract, shellfish oil, anise seed oil, and essence of apple).

Camera stations were monitored from early August 2011 to early June 2012 (341 camera-weeks in total). A total of nine photographs of Wolverines were recorded at 3 of the 17 stations (Figure 1) between 8 August and 21 September 2011. The time period between individual photographs ranged from one to 38 days.

Hair snags and camera data were retrieved from the stations every 7 to 10 days. All barbs were cleaned of any residual hair using a propane torch. Camera images recorded Wolverine points of entry across the barbed wire, so that hair snags could be matched with the individuals in the photographs.

Not all individuals could be identified; however, at least two individuals, i.e., individual no. 1 (Figure 2) and individual no. 2 (Figure 3) could be differentiated based on body size. Individual no. 2 appeared thinner than individual no. 1. A comparison of body depths, measured from the original photographs and corrected for the distance from the camera to the subject, confirmed individual no. 1 had a body depth at least 70%

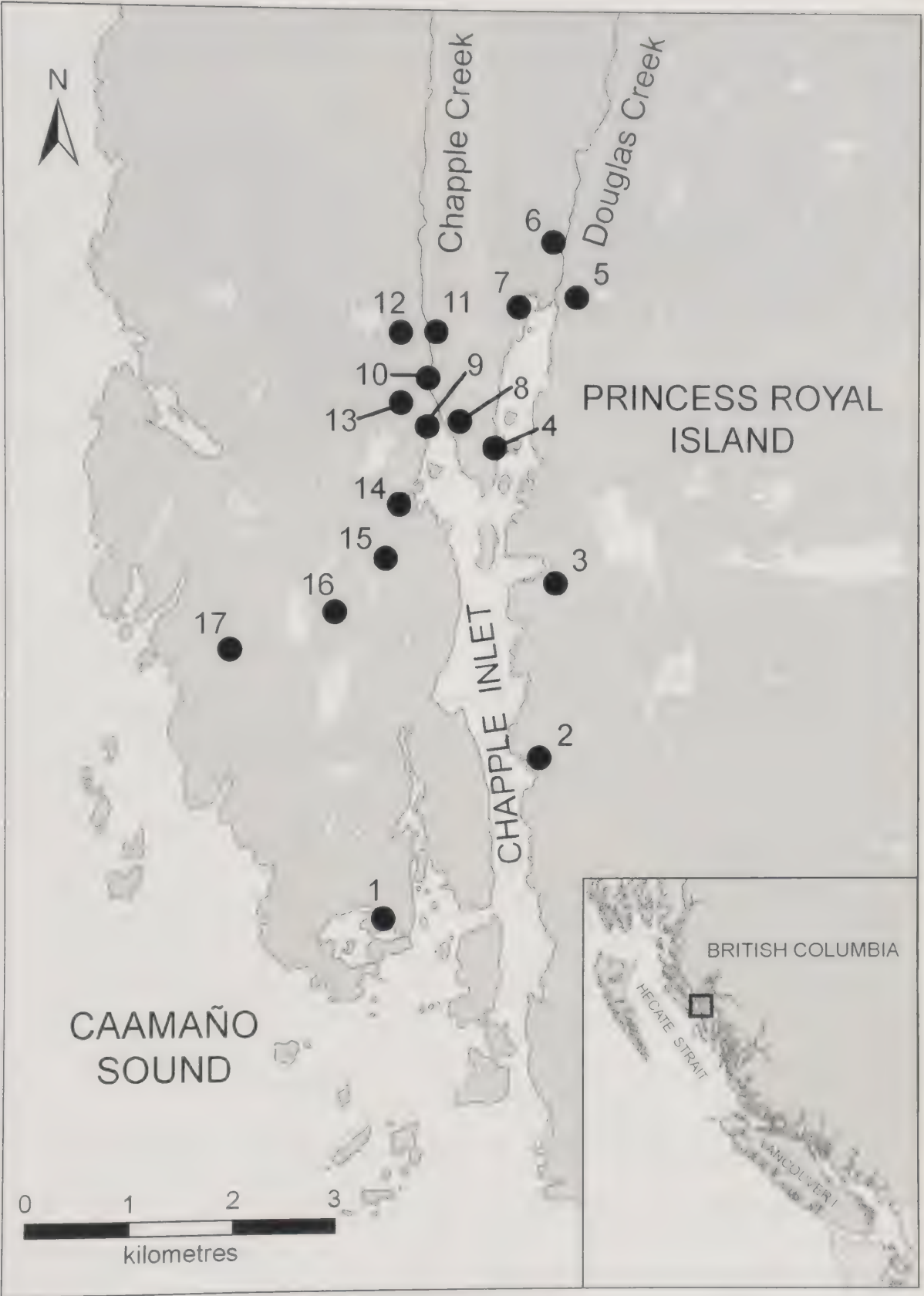


FIGURE 1. Study area showing location of camera stations. Wolverines (*Gulo gulo*) were recorded at 3 stations (stations 2, 3, and 5) between 8 August and 21 September 2011.



FIGURE 2. Wolverine (*Gulo gulo*) no. 1, photographed August 13, 2011 at station no. 5 near Douglas Creek on Princess Royal Island, British Columbia.

larger than individual no. 2. Hair snag samples using whole hairs of approximately the same length from these two individuals were analyzed for isotopic signatures.

Laboratory procedures

Carbon and nitrogen isotopic signatures were analyzed by Aquatech Enviroscience Laboratories Inc., Victoria, British Columbia, using standard methods and instrumentations. Samples of Wolverine hair were cleaned of surface oils using repeated rinses of a 2:1 chloroform : methanol solution and then dried in an oven at 60°C for 12 hrs. Hair in the amount from 0.2 to 0.4 mg was cut and placed in a tin cup. The amount of sample or standard analyzed in the procedure was based on the criterion that the range of nitrogen must be within 0.02 to 0.2 mg.

Carbon and nitrogen isotope compositions were determined using thermal combustion elemental analyzer Costech ECS 4010 (Costech Analytical Technologies Inc., Valencia, California) coupled with a continuous flow elemental analysis isotope ratio mass spectrometer (EA-IRMS) (Thermo Finnigan DELTA-plus Advantage, ThermoFinnigan Inc., Bremen, Germany). Each batch of samples included quality assurance and quality control (QA/QC) samples: three "working standards" analyzed before and after each batch of samples, a sample duplicate, and a procedural blank. The carbon and nitrogen contents of hair samples were determined based on the calibration created using EA-IRMS analysis of acetanilide used as a calibration standard.

Both carbon and nitrogen isotope data are reported in conventional δ -notation in units of per mil (‰) with respect to the Pee Dee Belemnite (PDB) standard and atmospheric nitrogen (air) for ^{13}C and ^{15}N , respectively:

$$\delta X_{\text{sample}} (\text{‰}) = (R_{\text{sample}} - R_{\text{standard}}) / R_{\text{standard}} \times 1000$$



FIGURE 3. Wolverine (*Gulo gulo*) no. 2, photographed September 6, 2011 at station no. 2 near the shoreline of the east side of Chapple Inlet, Princess Royal Island, British Columbia.

where X is ^{13}C or ^{15}N and R is a corresponding ratio $^{13}\text{C}/^{12}\text{C}$ or $^{15}\text{N}/^{14}\text{N}$. R_{standard} for ^{13}C and ^{15}N corresponds to the ratio of $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ in their respective international standards, PDB and Air.

All Wolverine hair samples were normalized against international reference standards: IAEA-N1 (ammonium sulphate reference material certified by the International Atomic Energy Agency) with a $\delta^{15}\text{N}$ value of 0.40‰, IAEA-N2 with a $\delta^{15}\text{N}$ value of 20.30‰, Sucrose ANU with a $\delta^{13}\text{C}$ value of -10.47‰, and NBS-22 OIL with a $\delta^{13}\text{C}$ value of -29.73‰. Long-term performance of the mass spectrometer was monitored by analysis of secondary reference material in every batch: acetanilide with carbon and nitrogen contents of 71.09% and 10.36%, respectively, DORM-2 dogfish muscle certified reference material from NRC with a $\delta^{15}\text{N}$ value of 14.33‰, and caffeine with a $\delta^{15}\text{N}$ value of -0.95‰. The long-term standard deviation of the values obtained from measurements of the secondary laboratory standards were within 0.1 and 0.25‰ for ^{13}C and ^{15}N , respectively.

Diet analysis

The processes of incorporating stable isotopes into animal tissues are outlined by Ben-David and Flaherty (2012). Isotope signatures in animal tissue are the consequence of the source (i.e., food or prey) and the fractionation of the metabolic steps into that tissue. Isotope signature values for potential prey items of Wolverine found on Princess Royal Island and correction factor values for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ fractionation were taken from the literature. Salmon values were taken from Satterfield and Finney (2002), Mule Deer

(*Odocoileus hemionus*) from Darimont *et al.* (2009), microtines from Ben-David *et al.* (1997), and Blue Grouse from Dalerum *et al.* (2009).

Results

The isotope signatures from the two Wolverines on Princess Royal Island as well as those from Dalerum *et al.* (2009) are shown in Table 1 along with the values corrected for trophic fractionation ($\Delta\delta$).

The average value and standard error for $\delta^{15}\text{N}$ presented by Dalerum *et al.* (2009) from Wolverine bone collagen was $7.2 (\pm 0.2)$ in an area of Alaska populated with spawning Chum Salmon. When corrected for fractionation, the $\delta^{15}\text{N}$ values ranged between approximately 1 and 4 (Figure 4). The data from Princess Royal Is-

land are from hair samples; however, Hilderbrand *et al.* (1996) found little or no difference in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values between bone collagen and hair taken from House Mice (*Mus musculus*), European Rabbits (*Oryctolagus cuniculus*), and American Black Bears (*Ursus americanus*) fed a constant diet.

Assuming that collagen and hair have similar trophic fractionation values, a $\delta^{15}\text{N}$ value of 12.4 (or 7.7 corrected for trophic fractionation) found in Wolverine hair from Princess Royal Island would indicate a substantial level of marine protein, most likely from salmon, in the diet of Wolverine no. 1. The isotope signature for Wolverine no. 2, on the other hand, indicates a diet of Columbian Black-tailed Deer and microtines (Figure 4).

TABLE 1. Wolverine (*Gulo gulo*) hair isotope values, corrected for fractionation ($\Delta\delta$), for two individuals on Princess Royal Island, British Columbia, and for Wolverine collagen (average value) from Alaska and isotope signatures for prey items from Princess Royal Island.

Isotope signatures	$\delta^{13}\text{C}$	$\Delta\delta^{13}\text{C}$	$\delta^{13}\text{C}$ corrected	$\delta^{15}\text{N}$	$\Delta\delta^{15}\text{N}$	$\delta^{15}\text{N}$ corrected
Wolverine						
Princess Royal Island, no. 1	-21.3	3.2 ¹	-24.5	12.4	4.7 ¹	7.7
Princess Royal Island, no. 2	-24.4	3.2 ¹	-27.6	6.9	4.7 ¹	2.2
Collagen (Alaska average) ²	-20.5	2.9	-23.4	6.7	4.6	2.1
Prey						
Salmon ³	-19.9	-0.8		12.5	3.8	
Microtines ³	-26.5	2.9		2.9	4.6	
Mule Deer ²	-27.4	3.5		3	4.9	
Blue Grouse ²	-23.7	2.9		2.8	4.6	

¹Mule Deer, Blue Grouse, and microtine average.
²Values from Dalerum *et al.* (2009) and Mule Deer from Darimont *et al.* (2009).
³Salmon from Satterfield and Finney (2002) and microtines from Ben-David *et al.* (1997).

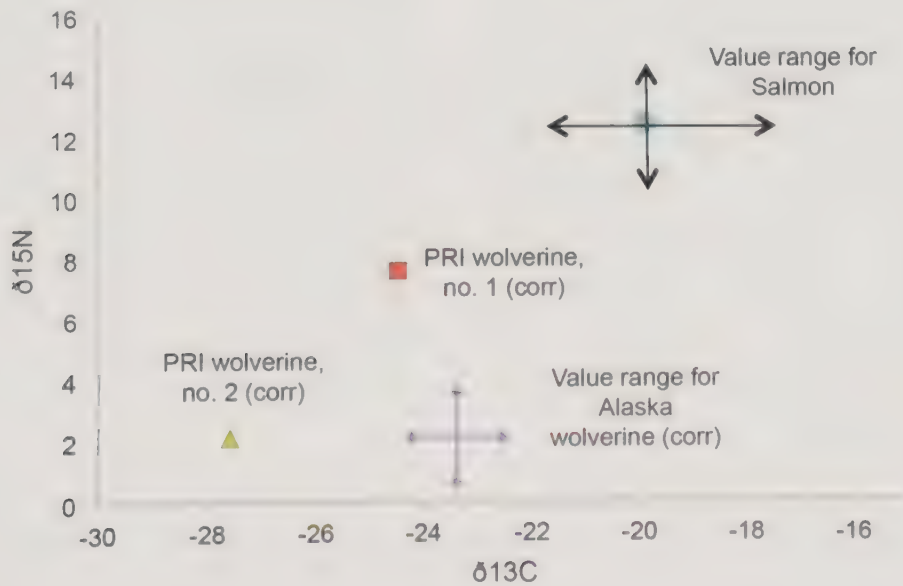


FIGURE 4. Isotope signatures, corrected for trophic fractionation, from individual Wolverines (*Gulo gulo*) on Princess Royal Island (PRI) and a range of values from femur collagen of Wolverines from Alaska ($n = 37$) (taken from Dalerum *et al.* 2009) corrected for trophic fractionation. The range of values for salmon (*Oncorhynchus* spp.) ($n = 47$) from Alaska are taken from Satterfield and Finney (2002).

Discussion

While the evidence for the consumption of salmon by Wolverine comes from just one individual, the finding is noteworthy for two reasons. First, the isotopic signature is well outside the range that can be explained by a diet consisting exclusively of terrestrial vertebrates. Second, it is the first isotopic evidence of the consumption of salmon by this species.

It seems reasonable that Wolverines, now known to be on this coastal island, would exploit salmon carcasses. Ungulates, such as Moose (*Alces americanus*) and Caribou (*Rangifer tarandus*), which are commonly found in the diet of Wolverines elsewhere (Lofroth *et al.* 2007), are most likely not present on the island (Darimont *et al.* 2005, Shackleton 1999).

Further samples from individuals on Princess Royal Island or other coastal islands may reveal that salmon are part of the diet of some other coastal Wolverines.

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Attempted Conspecific Cavity Usurpation by Red-headed Woodpeckers (*Melanerpes erythrocephalus*)

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When breeding resources are scarce, intense competition for nest sites among cavity-nesting birds can result in agonistic encounters and cavity usurpation. Red-headed Woodpeckers (*Melanerpes erythrocephalus*) are known to usurp nest cavities from interspecific competitors, but the incidence of conspecific cavity usurpation remains unreported. We describe an attempted conspecific nest usurpation and depredation by a Red-headed Woodpecker in mixed-oak (*Quercus*) woodlands in northern New York State.

Key Words: intraspecific competition; nest cavity; Red-headed Woodpecker; *Melanerpes erythrocephalus*; usurpation; New York

Introduction

Cavity-nesting birds are often limited by the availability of suitable nest cavities, and competition over nest sites can be fierce, sometimes resulting in aggression and agonistic interactions (Jackson 1976; Kronland 2007). In some circumstances, certain cavity-nesting species will usurp nest cavities from inter- or intra-specific competitors, presumably because some benefit is incurred to the usurping individual or pair (Lindell 1996). Usurpation of nest cavities may increase individual fitness because cavity excavation is energetically expensive and can take several weeks to complete (Jackson 1976). Usurpation can also occur when abundance of suitable cavities is limited (Lindell 1996).

Red-headed Woodpeckers (*Melanerpes erythrocephalus*) are one such species that is known to forcibly usurp the nest cavities of interspecific competitors. Red-headed Woodpeckers have been documented usurping cavities from Red-bellied Woodpeckers (*Melanerpes carolinus*) (Ingold 1989), Northern Flickers (*Colaptes auratus*) (Kronland 2007), Hairy Woodpeckers (*Picoides villosus*) (Kronland 2007), Downy Woodpeckers (*Picoides pubescens*) (Schwab and Monnie 1959), and Mountain Bluebirds (*Sialia currucoides*) (Kronland 2007). However, whether Red-headed Woodpeckers will usurp, or attempt to usurp, conspecific nest cavities has not been reported or evaluated. Here, we describe an attempted conspecific nest usurpation by a Red-headed Woodpecker.

Study Area and Methods

All field observations were conducted on Fort Drum Military Installation, east of Watertown, New York (44°00'N, 75°49'W). The study area consists of a portion of approximately 1000 ha of the Installation composed of oak (*Quercus* spp.) woodlands where a small population of Red-headed Woodpeckers (9–15 adult pairs) regularly breeds. The study area is dominated by Northern Red Oaks (*Quercus rubra*) and White Oaks

(*Quercus alba*). A reduced number of Red Pines (*Pinus resinosa*) and Eastern White Pines (*Pinus strobus*) are also present.

We monitored this breeding population during two breeding seasons, from May to August in 2012 and 2013, by surveying the study area for breeding territories and nest cavities and subsequently monitoring reproductive success (protocol following Dudley and Saab 2003). Breeding pairs of Red-headed Woodpeckers are highly territorial, and we used this behaviour to spot-map individual territory boundaries (Atterberry-Jones and Peer 2010).

Results

During routine nest checks on 19 May 2013, at approximately 0745, we detected a territorial dispute between three individual Red-headed Woodpeckers near the nest tree of a known territorial pair. We had observed the territorial pair on more than four occasions in a 14.0 ha oak-dominated forest stand, and we identified their nest tree on 14 May 2013. The territorial pair was one of the first breeding territories to be established on the study area in 2013, and at least one of the individuals likely over-wintered on Fort Drum during 2012–2013. The nest tree was a Northern Red Oak snag located 60 m from the forest stand edge, and the nest cavity was in a dead limb 9.5 m from the ground and was roughly 90° horizontal facing 025°N.

Although none of the Red-headed Woodpeckers observed were individually marked, it was easy to differentiate between the territorial pair and the third individual because (1) the territorial pair would frequently engage in mating behaviour (chatter vocalizations and copulations) (Jackson 1976) at the nest cavity in between disputes and (2) the intruding individual would perch singly on tree limbs 10–40 m from the nest tree after being driven away from the nest cavity. We could not determine the sex of the individuals because Red-headed Woodpeckers are monomorphic. We made all

observations using 8× binoculars while seated ~30 m from the nest tree, and remained motionless to ensure that our presence did not influence the birds' behaviour.

From 0750 to 0935, we observed the intruding individual repeatedly attack the territorial pair and attempt to enter the nest cavity. The intruder would typically remain perched on a nearby tree and then attack the nest tree at ~2 minute intervals, often directing its attack at the nest cavity. The territorial pair would defend the nest cavity by consistently chasing the intruder away from the nest tree and frequently alarm calling; both territorial individuals participated in nest defense. On seven occasions, the intruder managed to land on or near (within 1 m of) the nest cavity, and in one instance was able to momentarily enter the cavity before being quickly evicted by a territorial individual.

This behaviour was markedly different from the behaviour that is typically observed during territorial disputes between neighbouring Red-headed Woodpecker pairs. These disputes often consist of brief agonistic encounters that occur near territory boundaries (Kilham 1958; Smith *et al.* 2000; JLB, personal observation). In this instance, the intruder targeted the territorial pair's nest cavity and made numerous repeated attempts to attack and enter the nest over an extended period of time (>1.5 hours). Furthermore, the entire altercation occurred well within the territory boundary (identified by spot mapping) of the territorial pair and not near the periphery, where most territorial disputes typically occur.

At 0935, the intruding individual was last seen being chased by a territorial individual away from the nest tree and was not observed again in the territory for 10 minutes. At 0945, after we had determined that the altercation had concluded, we inspected the nest cavity with a wireless peeper camera (Luneau and Noel 2010) to examine the nest contents and found the nest contained six intact eggs. The pair was eventually successful in fledging three young, on 23 June 2013, and the pair initiated a second brood on 1 July 2013.

Discussion

Based on our observations, we hypothesize there are only two possible behavioural explanations for the observed altercation: (1) the intruding individual was attempting to usurp the territorial pair's nest cavity and territory or (2) the intruder was attempting to depredate the nest contents but not usurp the cavity and territory. As mentioned above, this altercation differed markedly from typical Red-headed Woodpecker territorial disputes observed in this study and described elsewhere (Kilham 1958; Reller 1972; Jackson 1976). Typical territorial disputes are often brief agonistic encounters. Therefore, the observed altercation was likely an attempted nest usurpation or predation, particularly because the territorial pair's nest contained eggs that were being incubated.

We could not ascertain the origins of the intruding individual, but we suspect that it was not from a neighbouring territorial pair. At the time of the altercation, there were only two other known Red-headed Woodpecker territories in the study area (based on intensive surveys), and both were incubating their own clutches at the time in nests located in separate forest stands >500 m away. We therefore believe the intruder was likely a recently arrived migrant, as 19 May is near the average arrival date of migratory Red-headed Woodpeckers in Fort Drum (JSB, unpublished data) and several new breeding territories were established in the study area a few days following the altercation.

Red-headed Woodpeckers are considered "weak" excavators, and cavity excavation in this species can take more than two weeks to complete (Jackson 1976). Furthermore, Red-headed Woodpecker pairs that usurp interspecific cavities nest on average six days earlier than pairs that excavate their own cavities (Kronland 2007). It is therefore possible that, upon arrival in the breeding grounds, the intruding individual attempted to usurp the nest cavity and territory to circumvent the time required to establish a territory and excavate a cavity.

Red-headed Woodpeckers are considered an aggressive species that is behaviourally dominant over many other cavity-nesting birds (Kilham 1958; Reller 1972), and Red-headed Woodpeckers are known to engage in interspecific cavity usurpation and predation (Kronland 2007). In a study of Red-headed Woodpecker cavity usurpation in southeastern Montana, Kronland (2007) described the incidence of interspecific cavity usurpation, estimating that over 20% of Red-headed Woodpecker nest cavities were secured by usurpation, but did not describe any incidence of conspecific cavity usurpation. Given their tenacity in usurping interspecific nest cavities (Schwab and Monnie 1959; Ingold 1989; Kronland 2007), it would not be surprising if Red-headed Woodpeckers usurp and depredate conspecific nests as well.

Interestingly, the territorial pair later initiated a second brood in the same nest cavity upon successfully fledging the first brood. Although it is unlikely that the attempted cavity usurpation and decision to initiate a second brood are related, we report it here because, to our knowledge, there have been no previous reports of double-broods by Red-headed Woodpeckers at northern latitudes. Double-broodedness is common in the southern portion of the Red-headed Woodpecker's range (Ingold 1987), and apparently also occurs in the northeastern United States despite inherently shorter breeding seasons.

The Red-headed Woodpecker has experienced a substantial range-wide population decline in recent decades. There are few estimates of reproductive success, and the factors influencing nest survival are poorly understood (Smith *et al.* 2000). The incidence of conspecific cavity usurpation or depredation by Red-

headed Woodpeckers is currently unreported, and it warrants further investigation to elucidate its influence on local reproductive success and population dynamics, particularly within small populations and populations with patchy distributions.

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Attempted Predation of a Diurnally Active Spotted Bat (*Euderma maculatum*) by a Belted Kingfisher (*Megasceryle alcyon*)

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Jung, Thomas S. 2013. Attempted predation of a diurnally active Spotted Bat (*Euderma maculatum*) by a Belted Kingfisher (*Megasceryle alcyon*). *Canadian Field-Naturalist* 127(4): 346–347.

Most species of bats (Chiroptera) are nocturnal, and diurnal activity is only occasionally reported. I observed a Spotted Bat (*Euderma maculatum*) flying along a lakeshore in the Okanagan Valley of southcentral British Columbia, Canada, in mid-afternoon. The Spotted Bat flew along the shoreline and drank from the lake. During the course of its flight, the Spotted Bat was attacked by a Belted Kingfisher (*Megasceryle alcyon*), but it escaped. This is the first reported observation of a Spotted Bat active during the daytime. It is also the first reported observation of attempted predation of a bat by a Belted Kingfisher. It is not known how prevalent daytime activity is in Spotted Bats, but this observation supports the hypothesis that predation risk may be high for bats that are active during the day.

Key Words: Belted Kingfisher; *Megasceryle alcyon*; Spotted Bat; *Euderma maculatum*; diurnal activity; predation; British Columbia

It is believed that most species of bats (Chiroptera) are nocturnal as an evolutionary means to avoid competition with, and possible predation by, diurnal birds (Speakman 1991; Jones and Rydell 1994; Rydell and Speakman 1995; Russo *et al.* 2011). Nocturnality is therefore entrained in most (if not all) species of Microchiropteran bats. For instance, even in high latitudes, where the period of darkness is short or altogether absent during certain times of the year, bats are active at the relatively darkest time of the day (i.e., near midnight; Speakman *et al.* 2000; Talerico 2008). Occasionally, however, observations of diurnal activity by bats are reported in the literature (e.g., Speakman 1990; Ciechanowski and Anikowska 2007; Hendricks and Hendricks 2010; Russo *et al.* 2011). Reasons for diurnal activity by bats are not clear, but may include the need to drink or forage (Speakman 1990, 1991). Regardless, diurnal activity by bats could come at the cost of increased risk of predation by birds (Speakman 1991; Speakman *et al.* 1994; Fenton *et al.* 1994; Lima and O’Keefe 2013). Though, obtaining evidence for this hypothesis is challenging, given the irregularity of daytime activity in otherwise nocturnal bats (Lima and O’Keefe 2013). Here, I report an observation of attempted predation of a diurnally active Spotted Bat (*Euderma maculatum*) by a Belted Kingfisher (*Megasceryle alcyon*).

On 27 August 2013, at approximately 14:35 Pacific Daylight Time (PDT), an unidentified bat was observed flying about 5 m above a campground road at Vaseux Lake Provincial Park (49.298, –119.530), about 6 km south of Okanagan Falls, British Columbia, Canada. The bat flew among an open canopy stand of mature Ponderosa Pine (*Pinus ponderosa*) and arced toward nearby Vaseux Lake (M. M. Clyde, personal communication). At 14:39 (PDT) while wading about 10 m off the eastern shore of Vaseux Lake, I observed a Spotted Bat. The Spotted Bat was about 0.3 m above the surface of the water and flew within 3 m of me. Given the prox-

imity, I was able to positively identify it as a Spotted Bat, based on the large pink ears and the distinctive black dorsal pelage with large white spots (Nagorsen and Brigham 1993). The Spotted Bat remained within 20 m of the lakeshore, and I observed it drinking from the lake four times during a flight that undulated up-and-down between 0.3 and 3.0 m above the lake.

When the Spotted Bat was about 80 m away from me, a Belted Kingfisher perched on a tree along the shoreline dove at the Spotted Bat but missed it. The Belted Kingfisher quickly gained altitude to about 7 m above the surface of the lake and dove at the Spotted Bat again. The Spotted Bat easily avoided the Belted Kingfisher and continued down the lakeshore for another 80–100 m until it was out of sight. The Belted Kingfisher did not pursue the Spotted Bat further. The attack by the Belted Kingfisher lasted ≤ 30 seconds. It was a sunny day and the temperature was about 29°C.

This observation is of interest from several perspectives. To the best of my knowledge, this is the first record of diurnal activity by a Spotted Bat. Why the Spotted Bat was active during the day is unknown. Spotted Bats in the southern Okanagan Valley generally emerge to forage later in the day than sympatric species of bats (Wai-Ping and Fenton 1989) and they mostly forage over terrestrial habitats (Woodsworth *et al.* 1981; Leonard and Fenton 1983), so flying in daylight over a lake is unusual. It was not an overly hot day; however, diurnal roosts of Spotted Bats in the southern Okanagan Valley tend to be on tall, south-facing cliffs that may experience increasingly high temperatures throughout the day (Woodsworth *et al.* 1981; Leonard and Fenton 1983; Wai-Ping and Fenton 1989). The most plausible explanation was that the Spotted Bat needed a drink to reduce dehydration. Hendricks and Hendricks (2010) similarly observed unidentified species of myotis (*Myotis* spp.) drinking during daylight. It is not known how prevalent diurnal activity is in Spotted Bats, particularly related to drinking. This

observation is also the first known record of a Belted Kingfisher attempting to prey on a bat. Belted Kingfishers are primarily piscivores, but they will occasionally prey upon riparian small mammals (Kelly *et al.* 2009). For example, Cairns (1998) reported an American Water Shrew (*Sorex palustris*) in the diet of a Belted Kingfisher from Nova Scotia. However, the main scientific value of this observation is that, in conjunction with similar reports (e.g., Miller 1962; Fenton *et al.* 1994; Lefevre 2005), it lends further support to the hypothesis that diurnal activity by bats may incur an increased risk of predation by diurnal birds (*sensu* Speakman 1991; Fenton *et al.* 1994; Speakman *et al.* 1994; Lima and O'Keefe 2013).

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Great Plains Ladies'-tresses, *Spiranthes magnicamporum*: Disjunct in Eastern Ontario and a New Orchid Species for the Ottawa District and Lanark County

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Reddoch, Joyce M., Paul M. Catling, and Allan H. Reddoch. 2013. Great Plains Ladies'-tresses, *Spiranthes magnicamporum*: disjunct in eastern Ontario and a new orchid species for the Ottawa District and Lanark County. *Canadian Field-Naturalist* 127(4): 348–351.

We report the discovery of Great Plains Ladies'-tresses, *Spiranthes magnicamporum* (Orchidaceae), in eastern Ontario, 250 km east of its previously known eastern occurrence in Ontario. The population of more than 500 flowering plants (in 2013) was confined to Prairie Dropseed, *Sporobolus heterolepis*, grasslands within the Burnt Lands Alvar. Peak flowering was in late September, two weeks later than that of Nodding Ladies'-tresses, *Spiranthes cernua*, in the same area.

Key Words: Great Plains Ladies'-tresses; *Spiranthes magnicamporum*; Ottawa District; Lanark County; eastern Ontario; Burnt Lands Alvar; alvar; disjunct population; range extension

The Great Plains Ladies'-tresses, *Spiranthes magnicamporum* Sheviak, is an orchid that occurs in the North American Great Plains from extreme southeastern Manitoba to central Texas (Sheviak and Brown 2002). There are also a number of widely spaced disjunct populations, especially eastward, including southwestern Ontario (Sheviak and Brown 2002). There, *S. magnicamporum* has been recorded in 10 counties between Lakes Erie and Huron as far east as the Niagara Region, Wellington County, and Bruce County (Catling 1976; Oldham and Brinker 2009). In 2011, it was found 150 km farther east, in the Carden Alvar in the City of Kawartha Lakes (M. J. Oldham, personal communication; specimens at the Royal Ontario Museum Herbarium, Toronto, TRT; acronyms follow the Global Registry of Biodiversity Repositories, <http://grbio.org>). *Spiranthes magnicamporum* is classified as vulnerable (S3) in Ontario and uncommon (G4) globally (Oldham and Brinker 2009).

On 18 September 2013, PMC discovered this species in The Burnt Lands in eastern Ontario near Ottawa, 250 km east of the Carden Alvar (ONTARIO: Lanark Co.: N end of Burnt Lands Provincial Park (Nature Reserve), at 45.26931, –76.19777, 10 October 2013, P. M. Catling 2013-863, DAO 886623). This discovery is the most northeastern disjunct population of *S. magnicamporum* so far reported and is a new species for the Ottawa District (the area of southeastern Ontario and southwestern Quebec within 50 km of the Peace Tower on the Parliament Buildings in Ottawa) and for Lanark County (Reddoch and Reddoch 1997; White 2013*).

The Burnt Lands, located 4 km north and northeast of Almonte, Mississippi Mills, Ontario, is a 15 km² area of provincially significant flora and fauna (Brunton 1986*). The publicly owned lands within this area, which straddles the boundary between Lanark County and the City of Ottawa, comprise the Burnt Lands

Provincial Park (Nature Reserve). The bedrock is Paleozoic limestone and dolomite of the Ottawa Formation (Bélanger and Harrison 1980). Large open expanses of The Burnt Lands are alvar meadows, areas of natural grassland vegetation in shallow soil over relatively flat calcareous bedrock (Brunton 1986*; Belcher *et al.* 1992; Catling 1995; Catling and Brownell 1995, 1999). The alvar meadow habitat in the northwestern section is about 2 km² in extent, with bedrock that is locally flat with gentle slopes between one flat expanse and the next. At the bases of these slopes in moist to wet seepage areas are meadows dominated by the provincially significant (S3) Prairie Dropseed (*Sporobolus heterolepis* (A. Gray) A. Gray) (Figure 1). The *Spiranthes magnicamporum* plants are confined to these open meadows as scattered individuals and occasional pairs. (The scientific names marked in boldface above and below are species highly (50–100%) confined, in southern Ontario, to alvars (Catling 1995, 2013).)

The other major associate for *Spiranthes magnicamporum* here is the provincially significant (S2–S3; M. J. Oldham, personal communication) Sheathed Dropseed (*Sporobolus vaginiflorus* (Torr. ex A. Gray) Alph. Wood var. *vaginiflorus*). Other associates observed within 1 m of the orchid plants are the grasses Rough Bentgrass (*Agrostis scabra* Willd.), Kalm's Brome (*Bromus kalmii* A. Gray), Spike Muhly (*Muhlenbergia glomerata* (Willd.) Trin.), Wiry Witchgrass (*Panicum flexile* (Gattinger) Scribn.), and Beaked Dropseed (*Sporobolus vaginiflorus* (Torr. ex A. Gray) Alph. Wood var. *inaequalis* Fern.), as well as Crawe's Sedge (*Carex crawei* Dewey), Blue-eyed Grass (*Sisyrinchium montanum* Greene), Wild Strawberry (*Fragaria virginiana* Miller), Northern Bog Violet (*Viola nephrophylla* Greene), Self-heal (*Prunella vulgaris* L.), Small Skullcap (*Scutellaria parvula* Michx.), False Pennyroyal (*Trichostema brachiatum* L.), Balsam Groundsel



FIGURE 1. Prairie Dropseed (*Sporobolus heterolepis*) alvar meadow habitat of Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in the Burnt Lands Alvar, eastern Ontario, 19 September 2013. The surrounding forest consists of White Spruce (*Picea glauca* (Moench) Voss), Eastern White Cedar (*Thuja occidentalis* L.), Balsam Fir (*Abies balsamea* (L.) Mill.), and Eastern White Pine (*Pinus strobus* L.). Photo: A. H. Reddoch.

(*Packera paupercula* (Michx.) Á. Löve and D. Löve), and Oxeye Daisy (*Leucanthemum vulgare* Lam.). The pH of the moist to wet soils at a few locations where *Spiranthes magnicamporum* plants were rooted ranged from 7.2 to 7.8, as measured with a Hanna Instruments HI 199121 pH test kit (Hanna Instruments, Woonsocket, Rhode Island).

Five hundred and twenty flowering plants of *Spiranthes magnicamporum* were counted within an area of 1 km² on 26 September 2013. At that time, most plants were in full flower, about two weeks later than the peak flowering of Nodding Ladies'-tresses, *Spiranthes cernua* (L.) Richard, which grows mostly on sands and in moist areas nearby. The heights of a sampling of flowering plants of *S. magnicamporum* ranged from 15 cm to 30 cm (mean 21 cm, $n = 38$). The flowers (Figures 2 and 3) had a strong, rich, complex, pleasant fragrance. The seeds from three plants were largely monoembryonic but with a small polyembryonic component.

Related species of *Spiranthes* are pollinated principally by bumble bees (*Bombus* spp.). Catling (1983) and Smith (2012) reported that *S. magnicamporum* was also pollinated mainly by this group of insects in Ontario and Minnesota, respectively. Sheviak (1982) reported Golden Northern Bumble Bee, *Bombus fervidus*, as a pollinator in North Dakota, and Hapeman

(1996*) observed Nevada Bumble Bee, *B. nevadensis* var. *americorum*, in Wisconsin. During a two hour afternoon visit to The Burnt Lands site, we observed seven different instances of bumble bees visiting consecutive flowers and sometimes also consecutive plants.

The Prairie Dropseed grasslands in The Burnt Lands are equivalent to grassland habitats in the Great Plains. They are considered to be a relict from early post glacial times (approximately 10 000 BP), when they formed a continuum from the Ottawa Valley westward in front of the receding Wisconsin ice sheet (Catling and Brownell 1995). The presence on The Burnt Lands of a flightless leafhopper (Homoptera: Cicadellidae: *Memnonia panzeri*) that feeds only on Prairie Dropseed supports this view (Hamilton and Whitcomb 2010). The insect is unlikely to be present in this isolated easternmost habitat unless the habitat was once essentially continuous. Continuity of open habitat in front of the receding ice front is also supported by plant distributions (Catling and Brownell 1995). Prairie Dropseed reaches its northeastern limit in eastern Ontario and southern Quebec (Peterson *et al.* 2007). The largest stands of this kind of prairie east of disjunct stands in the northern Lake Huron region are on the Burnt Lands Alvar (PMC, personal observation). Considering its narrow confinement to The Burnt Lands and its close



FIGURE 2. Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in the Burnt Lands Alvar, eastern Ontario, 19 September 2013. Photo: J. M. Reddoch.

association with the Prairie Dropseed grasslands, *Spiranthes magnicamporum* may also be an isolated post glacial relict on the Burnt Lands Alvar.

The Flora of North America distribution map for *Spiranthes magnicamporum* shows seven disjunct populations east of the main range, spaced several hundred kilometres apart (Sheviak and Brown 2002). Given the multiple disjunct populations, it would not be surprising if this species exists in other eastern prairie-like localities, especially those underlain by limestone and dolomite bedrock. The most obvious additional possibilities for disjunct occurrences in the east are the limestone plateaus in New York State east of Lake Ontario. A search for Prairie Dropseed grasslands along the trail in one of these plateaus, the Chaumont Barrens, in 2013, did not reveal any Prairie Dropseed plants, but Prairie Dropseed is extensive in the state and occurs in other places near Chaumont and in the nearby alvars at Lucky Star and Limerick (Catling and Brownell 1995). Remnants of the once extensive alvars of the Napanee Plain in eastern Ontario are also areas of potential occurrence, but Prairie Dropseed grassland is now very limited in this region.



FIGURE 3. Flowers of Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in the Burnt Lands Alvar, eastern Ontario, 19 September 2013. Photo: J. M. Reddoch.

It is possible that the drought in 2012 and the very wet summer in 2013 in the eastern Great Lakes region may have resulted in more flowering of *Spiranthes magnicamporum* than usual. Other rare vascular plant species in eastern Ontario alvars, notably Ram's-head Lady's-slipper (*Cypripedium arietinum* R. Brown) and Cooper's Milk-vetch (*Astragalus neglectus* (Torrey & A. Gray) E. Sheldon), also produced large and robust populations in 2013 (D. F. Brunton, personal communication). *Spiranthes magnicamporum* may not appear in alvar meadows in some dry years, when alvar vegetation is generally suppressed.

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A Tribute to Laurie Lynn Consaul, 1960–2012

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Gillespie, Lynn. 2013. A tribute to Laurie Lynn Consaul, 1960–2012. *Canadian Field-Naturalist* 127(4): 352–357.

Born in Bracebridge, Ontario, on 22 March 1960, Laurie Lynn Consaul grew up in Fort William and Kapuskasing in northern Ontario and, after the age of 11, in Alliston in southern Ontario. She completed her undergraduate degree in plant sciences at the University of Western Ontario (UWO) in London in 1983. Her honours research thesis was *Changes in Chloroplast Proteins During Leaf Development in Vicia faba* L. (Fabaceae).

Switching her research interests to plant systematics, a field that would become her lifelong passion, Laurie moved to Ottawa to continue her studies under John McNeill at the University of Ottawa. In 1988, she completed her M.Sc. Her thesis was *The Biosystematics of Polygonum lapathifolium* L. (Polygonaceae) in North America. Returning to the University of Western Ontario (1986–1990), Laurie worked for Jim Phipps in a variety of roles as research assistant, helping with his systematic research on *Crataegus*, as assistant herbarium curator, and as assistant curator of the UWO Sherwood Fox Arboretum. Her work on *Crataegus* and *Polygonum*, two taxonomically difficult genera, marked the beginning of a passion for challenging taxa.

In 1990, Laurie moved back to Ottawa to begin work as a research assistant at the Canadian Museum of Nature, the start of a 22-year career with the Museum. Working within the Botany group, Laurie was instrumental in the success of numerous research projects, varying in subject from lichens to grasses and other arctic plants. Working with Irwin Brodo, she learned much about lichens and assisted in preparing and editing his monumental book *Lichens of North America*. Laurie worked extensively with Susan Aiken on arctic grasses, the grass genus *Festuca*, and the arctic flora. As project assistant, author, and editor of the interactive CD and web-based *Flora of the Canadian Arctic Archipelago* (Aiken *et al.* 2007), she was instrumental in seeing this project through to completion.

Over her many years at the Museum, Laurie became a competent and experienced systematist, gaining a broad knowledge of botany and exceptional laboratory skills. She displayed a dedication to collections-based herbarium research. Passionate about research and extremely hardworking, she put in long hours when a project piqued her interest (which was often!). Detail oriented, Laurie kept voluminous notes, whether in the field or the lab. I have many memories of Laurie writ-



FIGURE 1. Laurie Consaul, near Parry Sound on Georgian Bay, Ontario, summer 2010. Photo: M. Armstrong.

ing her field notes and diary long into the cold arctic night while snuggled in her sleeping bag as I drifted off to sleep, exhausted.

With determination (and bravery!) Laurie decided to go back to school when she was in her 40s to obtain her Ph.D. Laurie took a leave of absence from the Museum to attend McGill University (2002–2008) under the supervision of Marcia Waterway at the Macdonald Campus. Through a combination of hard work and creativity, Laurie obtained her own funding through an Industrial Postgraduate Scholarship from the Natural Sciences and Engineering Research Council of Canada (NSERC) and several smaller awards and grants, allowing her to work on the systematics of *Puccinellia*, a perplexing group of arctic grasses that had long fascinated her.

Laurie combined painstaking growth experiments with equally detailed molecular and morphological analyses, successfully untangling the complex evolution of the diploid and polyploid species in the Canadian



FIGURE 2. Laurie Council at arctic plant research display at Natural Heritage Building, Canadian Museum of Nature, Gatineau (Alymer) Quebec, April 2011. Photo: L. Gillespie.

Arctic. Graduating in 2008, Laurie produced a superb dissertation, *The Role of Polyploidy in the Evolution and Systematics of Arctic Puccinellia* (Poaceae). The resulting series of papers is undoubtedly the most in-depth systematic study of any genus in the Canadian Arctic (Consaul *et al.* 2008a, 2008b, 2008c, 2010a, b).

Laurie was in my mind first and foremost an arctic botanist. We first met in the summer of 1991 at Alexandra Fiord, Ellesmere Island (where I was assisting at an entomology camp, my first trip to the Arctic). Laurie had helicoptered in for the afternoon to collect a few grasses. We both were astonished to come across another botanist so unexpectedly in so remote a place: I was delighted to meet another botanist passionate about arctic plants, and Laurie was pleased to meet someone who could direct her to her species of interest. We both caught the arctic bug that summer. Laurie had recently started her position as research assistant at the Canadian Museum of Nature, and I wouldn't arrive at the Museum for another three years. Although we didn't suspect it at the time, we would eventually spend 6 summers together in the Arctic.

I have the most wonderful memories of these summers with Laurie in the Arctic: long hikes over the open tundra across wet meadows and up mountains searching for interesting plants. Always on the lookout for birds, Laurie would marvel at the bird nests we unexpectedly found on the tundra and linger by small lakes, binoculars in hand. We enjoyed dinner together in the open air, hands warming around mugs of tea, contem-

plating the tundra and the sky. We spent hours upon hours in a small dome tent examining and pressing our plant collections, eventually emerging, unfolding our stiff legs, to enjoy the midnight sun, the long arctic twilight, and the wide-open spaces.

I remember well Laurie's determined and somewhat confused looks when she was examining her grasses. She chose to study a group of arctic grasses (genus *Puccinellia*) that was so taxonomically complex that few others had studied the group, and none to the degree that she would. I remember her delight when she discovered possible new species. One of these indeed was a new species, which she went on to describe and publish, naming it *Puccinellia banksiensis* after the island where she first collected it. Another summer several years later, on Victoria Island, we were hiking back to camp from the coast after a very long day and lots of plant collecting. Laurie and I were lagging behind the group, exhausted, when Laurie knelt down, shotgun slung over her shoulder (our protection against possible Polar Bears, *Ursus maritimus*). She had just discovered a new locality for *Puccinellia banksiensis*, the first for Victoria Island, and she was absolutely delighted. Only Laurie would have noticed this tiny inconspicuous grass while hiking for hours over thousands upon thousands of tiny grasses. To the rest of us they all looked so similar.

I vividly remember sitting with Laurie on a hillside on Melville Island — Laurie and I likely the only humans on this immense High Arctic island—watching an Arctic Wolf (*Canis lupus arctos*) family with three young pups. Later that same summer, we weathered our worst storm together at the Polar Bear Pass field station on Bathurst Island, enduring 36 hours of violent winds and horizontal snow with all radio communication down (this was before the days of satellite telephones). I convinced Laurie not to venture outside—I really thought she might blow away in the strong winds. That was her personality: although petite, she was tough, and never complained, preferring a smile through the worst the field could throw her way. Laurie was an excellent field companion and an extremely dedicated field botanist who loved the Arctic.

Laurie's first research trip to the Arctic was with Susan Aiken in 1990 to Ivvavik National Park of Canada in northern Yukon. Her last arctic adventure was in 2010 to the Belcher Islands in Hudson Bay, as the botanist on an ethnobotanical study. During the years in between, Laurie travelled throughout the Canadian Arctic, from Quttinirpaaq National Park of Canada on northern Ellesmere Island to Tuktoyaktuk National Park of Canada on the mainland Northwest Territories, and from Tuktoyaktuk to the Savage Islands off the southeastern tip of Baffin Island. In all, Laurie spent 11 field seasons in the Canadian Arctic, including 8 Canadian Museum of Nature field expeditions. As part of her Ph.D. program, Laurie led 2 arctic field expeditions, and from 2002 to 2005 she also undertook re-

search on the use of native plant species to stabilize and revegetate mine tailings at Voisey Bay, Labrador, Newfoundland and Labrador. Laurie's collections from the Arctic and elsewhere are listed in Table 1; she also made many other collections as part of a team on other expeditions.

Laurie's love of nature was by no means limited to vascular plants or the Arctic. She was a passionate birder, active with the Ottawa Field-Naturalists' Club (OFNC), partaking in local annual bird counts, competing in bird count competitions, and always on the watch for interesting birds. Wherever Laurie travelled, in the Arctic or on one of her many vacations with her husband, Mark, to faraway places, she delighted in nature, from lichens and mosses to the largest trees, from insects to birds, meticulously observing and always recording detailed notes.

Laurie was an active member of the OFNC starting in the early 1990s, when she moved back to Ottawa. She was a member of the Birds Committee from 1993 to 2002 and then again in 2010-2011. Serving as recording secretary for all of these years, she had a reputation for dedication, detail, and a job well done.

As a member of the OFNC Macoun Club Committee, Laurie took part in almost every planning meeting from 1992 to 1999 (five meetings a year in those days) and helped organize the weekly program for young naturalists. She lined up many good speakers; the Canadian Museum of Nature photocopy machine was reportedly a great place to engage her colleagues in conversation and persuade them to talk to the young members. In 1992, Laurie was part of a small sub-committee that established the field-trip safety practices for the Macoun Club still in use. From 1999 until



FIGURE 3. Laurie Consaul with *Plantago canescens*, Hornaday River, in Tuktut National Park, Northwest Territories, July 2009. Photo: L. Gillespie.

2002, she served as liaison with the Museum, which then housed the Macoun Club collections and library and provided meeting space. In the late 1990s, she took part in the Baillie Birdathon (the oldest sponsored bird count in North America) and directed her share of the funds raised to the Macoun Club, a welcome donation used to buy research equipment. Although less involved after the 1990s, Laurie always remained interested in what was going on in the Macoun Club.

As a member of the Motherflickers team from 1996 to 2003, Laurie took part in the annual Taverne Cup, a 24-hour competitive birdathon in eastern Ontario

TABLE 1. Laurie Consaul's series of collections held at the National Herbarium of Canada, Canadian Museum of Nature (CAN): a preliminary list, including year, number range, and localities.

Year	Collection numbers	Location
1984	1–454	Ontario; New York (U.S.A.)
1985	463–773	Ontario; Quebec; England
1990	813–1029	Inuvik (Nunavut), Ivvavik National Park of Canada (Yukon); Virginia (U.S.A.)
1991	1040–1054	Ellesmere Island and Baffin Island (Nunavut)
1992	1055–1066	Nova Scotia; Churchill (Manitoba)
1993	1080–1084	Baffin Island (Nunavut)
1994	1085–1094	Calgary (Alberta); Kimberley (British Columbia)
1995	1178–1204	Gatineau (Quebec)
1997	1100–1177	Cambridge Bay (Nunavut); Oxford Station (Ontario); Gatineau (Quebec)
1998	2004–2041, 2390	Ottawa (Ontario); Gatineau (Quebec); Burritts Rapids (Ontario)
1999	2042–2330	Ontario; Ellesmere Island, Axel Heiberg Island, Baffin Island, Devon Island, and Cornwallis Island (Nunavut)
2001	2402–2463	Melville Island (Nunavut); New Mexico (U.S.A.)
2002	2500–2732	Voisey Bay, Labrador (Newfoundland and Labrador)
2003	2733–2944	Voisey Bay, Labrador (Newfoundland and Labrador); Banks Island (Northwest Territories); Ellesmere Island and Axel Heiberg Island (Nunavut)
2004	2970–3212	Voisey Bay, Labrador (Newfoundland and Labrador); Resolute, Beechey Island, Cunningham Inlet, and Iqaluit (Nunavut);
2005	3222–3244	Voisey Bay, Labrador (Newfoundland and Labrador)
2010	3502–4345	Belcher Islands (Nunavut)

and western Quebec. Team members Christine Lewis and Jean Wylie recall Laurie as their note taker and archivist par excellence, keeping the team awake with food and song during the long hours. Motherflickers won four trophies in the recreational class, the Fothergill Trophy (for the highest number of species seen in a 24-hour period) in 1997 and the Judith Wilks Trophy (second highest number of species) in 2000, 2001, and 2002. Laurie was also actively involved with both of the Ontario Breeding Bird Atlas projects, including serving as a regional coordinator for Region 22 (Kemptville) in 2001–2002.

Laurie was dedicated to plant systematics, and she was recognized internationally as an expert in arctic plants and specifically *Puccinellia*. She authored 30 scientific publications, 10 as first author; 6 technical reports, including a status report on Blunt-lobed Woodsia (*Woodsia obtusa*) for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and an additional 5 popular natural history articles (see list of publications).

In addition to her studies on arctic *Puccinellia* cited above, she coauthored the very useful treatments of *Puccinellia* for the *Flora of North America* and the *Manual of Grasses for North America* (Davis and Consaul 2007a, 2007b). Laurie was a long-time member of the Canadian Botanical Association (a student member in the 1980s and a regular member from 1994), serving as secretary of the Systematics and Phytogeography section from 1995 to 1998 and as association secretary from 2009 to 2011.

In 2011, Laurie accepted a position as assistant professor in the Biology Department at Memorial University, St. John's, Newfoundland and Labrador. This was to be the pinnacle of her career, a goal Laurie had worked so hard and with such determination to obtain.

Just prior to her scheduled move to St. John's, Laurie became ill while attending the 2011 Canadian Botanical Association annual meeting in Halifax. Diagnosed with a brain tumour, she spent the next year and a half bravely fighting her illness, with the loving care and support of her husband, Mark. Laurie lost her battle with cancer on 18 December 2012. Canada lost an excellent arctic botanist and plant systematist, and many from across Canada and around the world lost a dear friend.

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Additional Comments

Mark Armstrong has provided the following: As Laurie's illness progressed in 2012, she decided that leaving legacies to places that were a special part of her life was something important. A legacy has been given to the Sherwood Fox Arboretum at the University of Western Ontario (UWO) in London, Ontario. Laurie's time at UWO as both a student and research assistant provided her with the foundation for a life spent in the exploration of our natural world. It is the intention that a garden in Laurie's memory be established close to where she worked. To the Canadian Botanical Association (CBA), a legacy has been left to help in meeting the CBA's objective of providing for students interested in the world of botany. This annual award will be given to a student whose interest in science is acknowledged by the CBA as being deserving of recognition. In addition, an annual contribution will be given to help with travel to the Canadian Arctic for a student studying arctic natural history. The Arctic held a special place in Laurie's heart, and this funding will give students the opportunity to experience this wonderful area of our land. A third legacy was given to the Ottawa Field-Naturalists' Club. This is an organization that gave Laurie particular enjoyment. She enthusiastically contributed to the endeavours of the OFNC's work in different areas. Laurie had a long-time association with the OFNC, and her legacy will be used in a variety of ways. Annual sponsorship of the winter bird seed program will start in 2013 in Laurie's memory. A contribution will commence in 2013 to McGill University, Macdonald Campus, to be used in a way that Laurie would endorse. It was at McGill that Laurie's dream of obtaining her Ph.D. became a reality in 2008. It is intended that this annual donation be used to support and further our knowledge of biology in a place that Laurie enjoyed studying and being in.

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A Tribute to John Roger Bider, 1932–2013

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John Roger Bider was born on 23 November 1932, the second son of Frédéric André Bider (who had emigrated from Switzerland) and Catherine Corcoran. He grew up in Valois, a district of Pointe-Claire on the island of Montréal, Quebec, an area that was considered to be rural at the time. His home was within walking distance of Lac St. Louis, at the convergence of the Ottawa River and the St. Lawrence River. Nearby and draining into the lake was a fabulous ditch, where Roger had his first encounters with Northern Pike (*Esox lucius*), with frogs, and with Muskrat (*Ondatra zibethicus*) tracks in the mud.

He developed interests in natural history, nurtured by his mother, and mechanical abilities, fostered by his father, who was involved in the construction industry. At the age of 13 he spent a summer on a progressive dairy farm. Over the next two summers, Roger was engaged in demolition and construction. He graduated from Macdonald High School in 1950. He spent two summers in northern Ontario involved in forest entomology and then another two summers in Lachine at the Quebec Fish and Game Muskellunge (*Esox masquinongy*) hatchery on Lac St. Louis. He was involved in the release of hatchery-reared muskies into Lac Tremblant.

Following two years as a student in the Faculty of Forestry at the University of New Brunswick, Roger operated a trout hatchery and lake management company for a couple of years at Lac Carré in the Laurentians, north of Montreal. His hatchery stock was delivered by truck or float plane to fishing clubs and outfitters all over the Laurentians. With these activities Roger developed a great love of the Laurentians, where he kept returning for the rest of his life. He eventually transferred to the Université de Montréal to complete an undergraduate degree and graduated with honours in biology in 1956. In that same year he married Marjorie Jean Morphew. Together they had six children: Timothy, Steven, Donna, Keith, Jeanette, and Marc.

Continuing at the Université de Montréal, he studied habitat use and animal activity by tracking Snowshoe Hares (*Lepus americanus*) for a master's degree under the supervision of Paul Pirlot, received in 1959. He enrolled in a Ph.D. program later that year at the University of Texas, basing his fieldwork at the Welder Wildlife Refuge in Sinton, Texas.



FIGURE 1. Roger Bider during a cruise on the St. Lawrence River, 1990. Photo: D. Bird.

Roger returned to Montreal in 1961 and taught general biology and invertebrate zoology at Loyola College. He then resumed his quest for a Ph.D., but this time at the Université de Montréal. While completing his Ph.D., also under Paul Pirlot, he replaced Jim Mosimann, who had accepted a position in the United States. Roger taught advanced animal ecology and introduced sand-tracking to the students. In doing so, Roger essentially introduced terrestrial animal ecology to an institution where the emphasis had been on aquatics. Although he was at the Université de Montréal for only a short period, testimonials indicate that Roger's unassuming approach and solid knowledge were much appreciated. Some of his students remained connected to him for more than 50 years, especially in relation to northern hydroelectric development projects (James Bay and the proposed Grande rivière de la baleine (Great Whale) project). He completed his Ph.D. in 1966. His innovative use of the sand-tracking technique, begun in coastal

Texas, led to research on animal behaviour and community ecology that he would pursue over the next 20 years with a series of graduate students.

Roger was appointed Assistant Professor of Wildlife Biology in the Department of Woodlot Management, Faculty of Agriculture, at Macdonald College, McGill University, Sainte-Anne-de-Bellevue, Île de Montréal, Quebec, in 1965. He remained at Macdonald College until he retired in 1996, progressing quickly through the ranks to Associate Professor in 1969 and then to Full Professor in 1975. He served as Chairman of the Department of Woodlot Management from 1970 to 1972 and, following the merger of Woodlot Management and Soil Science in 1973, served as Chairman of the Department of Renewable Resources from 1977 to 1983.

Roger's students at Loyola, the Université de Montréal, and Macdonald College quickly became aware that the conventional lecture was not his favoured platform. In those days, class sizes were much smaller and Roger preferred an informal atmosphere. At times, he would simply sit on a desk wearing his terry-cloth T-shirt and tell anecdotes about his experiences in the field. He was a master at keeping students interested while conveying fish and wildlife management concepts in a laid-back, conversational manner. Students developed great respect for him, operating as an equal; he was akin to a lovable older hockey coach.

One of us (GJD) attended those early classes and recalls the time when Roger indicated he would be travelling to Newfoundland for a seminar. He was asked if he could bring back a bottle of Screech. This was not a request one would have made of other teachers. At the first lecture following his return, there was a sense that he had acquiesced to the request, but the class had to wait to the end to find out. He was special to his students, and lifetime bonds were formed. It was in the field, as a true naturalist, that he excelled. Crossing an old field with Roger was a class and a lab session all rolled into one, and, if you were attentive, you arrived at the next fence a better naturalist.

He developed the wildlife biology program at McGill University, and the program flourishes today (under another rubric) and attracts significant numbers of students. He taught courses in vertebrate anatomy, natural history, principles of ecology, renewable resources, conservation, and fisheries and wildlife management. One very popular course he initiated in 1975 was Desert Ecology, drawing from his experience and early education in Texas and Arizona. There was keen competition to enroll in this field course (numbers were limited), which visited deserts in the southern United States for an intense three weeks of camping and exploring these most intriguing habitats.

Roger's study, *Animal Activity in Uncontrolled Terrestrial Communities as Determined by a Sand Transect Technique* (published in 1968), was a seminal work. This research and that of graduate students, most-

ly conducted at Lac Carré using sand-tracking, had a significant impact on the study of animal activity and behavior and ultimately wildlife management. He supervised 42 graduate students through to completion (5 Ph.D. degrees and 37 master's degrees). All together, 22 of the 42 were involved in sand-tracking.

During Roger's research career, the first major emphasis was a consideration of various factors that influenced daily activity in a wide variety of animals, ranging from insects through snakes, frogs, turtles, and small mammals to large carnivores. Later he was involved in an intensive study of Painted Turtles (*Chrysemys picta*) and other local turtle species. In response to a request from the federal Ministry of Agriculture and local farmers, Roger and his research group conducted studies to mitigate the impacts of pest Red-winged Blackbirds (*Agelaius phoeniceus*) on corn crops. Pat Weatherhead, then completing a Ph.D. at Queen's University in Kingston, Ontario, was engaged to oversee this effort, in which a notable number of graduate students were involved and which produced publications from 1977 to 1985.

In 1973, Roger shared a vision with a falconer from the United Kingdom of breeding Peregrine Falcons (*Falco peregrinus*) in captivity, with the objective of releasing the young into the wild to restore their numbers. Peregrine Falcons had become endangered due to eggshell thinning caused by the widespread use of organochlorines such as DDT. Roger brought together and chaired a group of McGill University professors from both the downtown Montreal campus and the Sainte-Anne-de-Bellevue campus with expertise in avian biology and poultry production to create the Macdonald Raptor Research Centre (MRRC), later known as the Avian Science and Conservation Centre (ASCC). More than 50 Peregrine Falcons were released on the Île de Montréal.

Besides its focus on the Peregrine Falcon, the Macdonald Raptor Research Centre became involved in the rehabilitation of sick, injured, and orphaned raptors and a program to educate the public about the plight of birds of prey in general. During the first year of the Centre's existence, Roger took on DMB, a master's candidate, to develop artificial insemination procedures for Peregrine Falcons in collaboration with two animal scientists. This eventually culminated in the production of the world's first Peregrine Falcon bred by artificial insemination and, later, the first Peregrine Falcon produced from frozen and thawed semen. DMB not only completed his Ph.D. at the Centre, but also went on to become its first director, in 1978. By 2012, the Avian Science and Conservation Centre had worked with close to 70 graduate students and produced over 200 papers in refereed scientific journals. The raptor rehabilitation program was transferred to the Faculté de médecine vétérinaire at the Université de Montréal, where the program developed into one of Canada's foremost rehabilitation and public education centres for

birds of prey. Subsequently, in the 1980s, the public education program was relocated to Roger's pet project—the Ecomuseum.

Other graduate students contributed significantly to Roger Bider's legacy. His former graduate students have become professors, as well as scientists with the Canadian Wildlife Service (Environment Canada), Fisheries and Oceans Canada, the Quebec ministries dealing with fisheries and wildlife, the Royal Ontario Museum, Hydro-Québec, Ontario Hydro, the Ontario Ministry of Natural Resources, Ducks Unlimited, the Nature Conservancy of Canada, Makivik Corporation, the Toronto Zoo, and consulting companies dealing with environmental impact (André Marsan et Associés, Lavalin, Stantec).

Somewhat peripheral to his academic responsibilities, Roger was engaged in a variety of environmental causes. In the early 1970s, he formed Public Awareness of Wildlife (PAW), a program which employed students using hand-reared wildlife to make people more aware of their natural environment. Around this time, the Quebec government established a bounty to kill Gray Wolves (*Canis lupus*), which were blamed for reducing White-tailed Deer (*Odocoileus virginianus*) populations in the province. Involving students and interested conservationists, PAW evolved into Public Awareness of Wolves, which was instrumental in convincing the Quebec wildlife branch (Ministère du Loisir, de la Chasse et de la Pêche du Québec) to repeal the bounty program.

From 1967 to 1969, Roger had a research contract with the Forestry Service, then part of the federal Department of Fisheries and Forestry and now part of Natural Resources Canada, to study the ecology of the Cinereus (Masked) Shrew (*Sorex cinereus*), which had been introduced onto the island of Newfoundland from New Brunswick to control the Larch Sawfly (*Pristiphora erichsonii*). At the time, Cinereus Shrews were advancing at a rate of 21 km/year across the island. Raymond Sarrazin, a graduate student, was field manager for the project.

Beginning in 1968, together with Douglas Pimlott and C. J. Kerswill, Roger was involved in the preparation of a background study for the Science Council of Canada examining scientific activities related to fisheries and wildlife resources. This gave him "incredible insights" (his words) into the sociological and economic aspects of wildlife management that influenced his teaching and approach to wildlife management.

Roger conducted environmental impact studies for La Grande hydro development near James Bay (Société d'Énergie de la Baie James), development of the Mirabel Airport, and the proposed Great Whale hydroelectric project. He advised the governments of Burundi, Burkina Faso, and Haiti concerning wildlife management issues. He sat on the Quebec Conseil consultatif de l'environnement in its various names for three three-year terms between 1973 and 1990. He also advised different federal and provincial gov-

ernment agencies about vertebrate pest management between 1986 and 1997.

Roger always sought different perspectives on the natural world he loved to study and reveal to others. He enjoyed seeing a given habitat from above. This was likely influenced by the aerial surveys he had done to locate American Beaver (*Castor canadensis*), Caribou (*Rangifer tarandus*), and other large ungulates during his environmental impact studies. One interesting quest for this different perspective involved his learning to fly a single-engine plane. He took the courses, learned to fly, and then was failed on a technicality when he attempted to land the plane at the closed airport near Lachute during his final test flight. That was it for him as a pilot.

Ultimately a major preoccupation was his development of an ecological park. Roger had already taken students on a one-week wildlife management field trip each year to Lac Carré, and as part of the Desert Ecology course he had taken students into the field for three weeks every two years to learn about deserts. Associated with the desert trips was a visit to the Arizona-Sonora Desert Museum in Tucson, which Roger had visited for the first time in 1965, when he received an award from the U.S. National Science Foundation to study desert biology at Arizona State University. This living museum impressed Roger with its innovative, bold, and interactive approach to interpreting the Sonoran Desert. It also provided a model for Roger's thinking about public education.

Meanwhile, Roger became part of a local group that was developing a project in Senneville, Quebec, called Parc écologique. The group's original ambition of incorporating ecological agriculture and wildlife interpretation was not realized but, in the process, Roger became aware of a tract of land at McGill University that was being used as a dump site. In this land, he saw the possibilities of his nature interpretation park. In 1981, a non-profit corporation, the St. Lawrence Valley Natural History Society, was formed to develop such a facility. In 1984, clean-up of the landfill and dump site over what was formerly a beautiful marsh was begun. By 1988, after Roger had been very actively involved in site clearing, negotiation with McGill, fundraising, and design and construction of buildings and enclosures, the Ecomuseum opened its doors to the public. From that point until he retired from McGill University, Roger spent every spare moment at or thinking about the Ecomuseum.

Roger never tired of introducing people to the juicy facts of life in the natural world. He loved the animals that were the key ingredients of his zoo. In this era, little money was available, and everything was done as frugally as possible. It was amazing what Roger accomplished under the circumstances. Roger readily acknowledged the significant role volunteers played in the development of the Ecomuseum.

Retirement in 1996 allowed Roger to devote all of his time to the Ecomuseum. While his wife, Marge, had to spend her time there as well just to see him, she certainly gave him tremendous support throughout. Roger was the director until 2005 and only in the couple of years prior to relinquishing this responsibility did he finally spend some time elsewhere. First Stéphane Poulin and then David Rodrigue were at his side until David Rodrigue became the executive director.

Roger was honored by the Société Provancher d'histoire naturelle du Canada with its award as "Un Gens d'action" in 1994 for establishing the Ecomuseum, also by the Fondation de la faune du Québec, by Bird Protection Quebec with the Education Award in 2008, and by the Ecomuseum in 2012, when its spectacular new aviary was named in his honour.

Through the Ecomuseum, Roger coordinated the collection of distribution data to produce Quebec's first atlas of reptiles and amphibians, in 1988, co-authored by Sylvie Matte. This valuable conservation resource is still being updated annually by Ecomuseum staff supported by the provincial government.

It was a delight walking in the woods with Roger Bider. He enjoyed recounting how plants and animals of the local community interacted with each other. He knew the different species of diverse taxonomic groups that comprised the community. He was an "old school" field naturalist, difficult to find these days among modern specialist biologists that often do not see the forest for the trees. Roger loved to explore and reveal the links that bring the diverse units together. He was at his best on field trips with his students, bringing the principles of ecology to life in real time. Whether it was in a pond, a stream, a meadow, a forest, or a desert, he was the consummate naturalist and teacher.

Roger was a keen observer of human nature. He could seem removed in a group setting, but he was in fact taking it all in. He rarely spoke about himself or revealed his feelings, but he enjoyed meeting new people from different walks of life to learn about their past and connections. He had an uncanny way of finding and attracting people who could advise him and support his vision, recognizing that their particular strengths and expertise could complement his own. In a relaxed set-

ting, Roger could play, be mischievous, and enjoy the odd prank.

Roger and Marge were keen baseball fans, supporting the Montreal Expos, particularly when they played at Jarry Park, and would have been season-ticket holders had smoking in the stands been prohibited at the time.

Roger was an innovator. Whenever he hit a roadblock, he would "drive" around it (or sometimes through it), finding alternatives to the original course of action to reach his objective. He was very adaptable and unconfined by practice and tradition. Once he had brought a project to fruition, he would move on to what he considered the next exciting challenge.

Roger died peacefully 29 April 2013 after a seven-year battle with Parkinson's disease. During that time, especially in the early stages, he did not remain idle. He remained interested in wildlife issues, good stories, and the Ecomuseum, and he even tried his hand at fly-fishing. His eldest son, Tim, took him on a difficult birding expedition to Trinidad to see Oilbirds (*Steatornis caripensis*) while he was in a wheel-chair. As his condition worsened, he remained conscious of the effects the disease was having on his body and his mind, ever the curious naturalist, and tried to communicate this to his children.

In the words of his colleague, Gus Mackenzie, "Roger was a unique person with an original approach to life". He was a highly memorable character who left his mark on his science and the projects he fostered. He will be fondly remembered by the interested public, the many students and docents he mentored, and the colleagues he worked with.

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Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

ZOOLOGY

In The Presence of Buffalo: Working to Stop the Yellowstone Slaughter

By Daniel Brister. 2013. WestWinds Press, P.O. Box 56118, Portland, OR, USA, 97296-0306. 115 pages, 16.99 USD, Paper.

As I read author Daniel Brister's book, *In the Presence of Buffalo*, I got chills from the visceral emotion it produced and the similarities that this book shares with some of my own experiences with wildlife research and protection. Like the author, I am from Cape Cod, Massachusetts, and am more awed by the wide-open spaces and mountains of the west than I am from the beauty of the coastal, flat terrain of the east coast. Although I have studied carnivores (mainly eastern coyotes or coywolves as I call them) for most of my professional life, bison have always been one of my favorite animals, and I regularly travel to the park to observe and film them. In fact, in my book *My Yellowstone Experience* I devote an entire section to bison, and weave bison throughout the storyline. I briefly mention the absurdity of bison being kept in the invisible (to animals) boundaries of Yellowstone National Park (YNP) because of a disease, brucellosis, which they have *never* transmitted to cattle (yet the disease originated from non-native European livestock). But to gain a true understanding of the discrimination and mindless hate that bison have and continue to receive, one must read *In the Presence of Buffalo*.

If *In the Presence of Buffalo* doesn't anger and inspire you to take action for one of North America's most magnificent animals, then I don't know what will. Brister has dedicated the last 15 years of his life to the Buffalo Field Campaign (BFC, www.BuffaloField-Campaign.org) to protect the bison, or buffalo as he prefers to call them, that live in and hopefully eventually around YNP. As Brister himself states, very few of the 2.5 million people who visit YNP and those who are awed by America's only continuously wild and genetically pure bison herd are aware that state (mainly the Montana Dept. of Livestock [DOL]) and federal agencies (including YNP) have engaged in the wanton slaughter of 3,500 of these magnificent animals in the past decade, solely because they wandered out of the delineated confines of YNP. In fact, more buffalo have been killed in the past decade than since the 1870s when they were nearly wiped off the planet, except for a small herd that hid within the protected confines of YNP, and which all of the bison currently living in the

park are descendants of. If you thought people like Buffalo Bill Cody, who claims to have killed 4,280 bison in a year and a half, were a thing of the past, then think again. Brister documents modern day agents who get tremendous joy and satisfaction of killing these great beasts. Yet the DOL refuses to discuss the motives behind the bison slaughter, especially considering that there is no evidence of wild, free-roaming buffalo spreading brucellosis to cattle. Considering that other animals, most notably elk, also carry brucellosis, Brister reveals that the true cause of the continued bison slaughter is bison competing for cattle for limited grass in country that is a poor habitat for cows.

In the Presence of Buffalo was written to document government misuse, see that the buffalo are honoured and respected, and stop the unnecessary slaughter. This short but inspiring narrative weaves personal reflections and stories of the present-day buffalo massacre with information gathered through historical, cultural, and scientific research. We see how Brister and other members of the BFC get arrested for standing up for buffalo on federally owned lands, while government agencies are seemingly immune to illegal activities like trespassing and disturbing protected species. The book has five chapters (92 pages) and explores the relationship between human beings and bison. Some of the accounts of government corruption, waste, and abuse will frustrate and no doubt motivate you to take action of your own. Most impressive are the 18 pages of notes and sources at the end of the book that cite and properly document this mistreatment, effectively making it fact, not opinion, that the American taxpayer has been cheated and ripped off by rogue government agencies, most notably the DOL. I learned so much from this book I took a page and half of notes, on a sheet of paper that I use as a bookmark, which is more than I normally write down for longer manuscripts.

Brister makes a strong case that the cattle industry believes they have entitlement to publically owned lands, and that they view the wild buffalo as unnecessary competition for their sacred cows. The hypocrisy of the cattle baron is very apparent as they want the government to not interfere with their lives yet they

are essentially the recipients of four forms of welfare through taxpayer-funded subsidies including predator control, drought and fire relief, fencing, and well below-cost grazing allotments on public land. In fact, taxpayers pay ten times as much (\$200 vs. \$20 Million) to support the grazing program around YNP than ranchers do through grazing fees. Worse, it takes 73 times the land to raise a cow in the Rocky Mountains surrounding YNP than it does in the more fertile Midwest. The question then remains, why are we allowing such a non-profitable and non-productive enterprise to occur on our federal lands surrounding the world famous YNP? After all, a publicly owned resource (bison) is being killed at taxpayer expense mostly on public land, all for a small special interest group.

Chapters three and four can be hard to stomach as the reader is taken into what I perceive as a dark time in our nation's history. In the chapter *Inseparable Destiny*, we learn of the disgusting discrimination and disrespect that Native Americans have received up to present times. We learn of the US government repeatedly breaking treaties and slaughtering Indians, as well as killing bison as a deliberate attempt to dis-empower native peoples. Modern day DOL agents are pictured laughing at an elder Lakota for praying over the bodies of slain buffalo. We also see the bison slaughter as a clash of cultural values. For Euro-Americans human comfort comes before animal survival, whereas Native Americans see all animals as equal to people.

In the chapter *Cattle and Control*, we see even more of the DOL's mistreatment of bison. Brister often gets the urge to run out and interfere with the DOL's hazing operations but realizes that his work requires control. If he acts out of spite or insult, he realizes DOL agents will only make it harder on the buffalo and it might erode their efforts to gain public support. In this section, Brister also goes back and discusses historical efforts to eliminate bison and adds that the fur trade, where millions of furs were shipped to the east coast via railroad, helped contribute to the near eradication of bison. He somberly notes that millions of buffalo were gunned down for the skin on their backs, their carcasses discarded and left to rot where they'd fallen. The 1870s was the bloodiest decade for buffalo, and it is also when there was an exponential rise in the number of cattle on the Great Plains.

Brister depicts graphic accounts of the cattle barons claiming public lands as their own and forcefully evicting or even killing homesteaders who tried to claim land. In fact, organized attempts by stock grower associations had militias go assassinate people that stood in their way, in order to maintain power and control. These thugs became so powerful that many of these murderers went on to become elected officials. In fact, the live-stock industry's use of intimidation and slaughter to eliminate bison and other competitors (including people) has continued to the present day, most notably with

their war on predators including wolves and coyotes. Amazingly, some in the modern day inter-mountain west still use threat and intimidation to get their way, even though much of what they do is being subsidized by the taxpayer on our public lands. Brister comments that he has never seen such horrendous human behavior than the way that the DOL treats such a beautiful, spiritual being, as the bison. Perhaps worse, even YNP – charged with preserving natural resources unimpaired for future generations – is now more likely to arrest citizens for trying to protect buffalo than to stop the unnecessary actions of the DOL.

In my own work to better protect carnivores, I have been told, "To care – as we do – is to be angry and discouraged and outraged by the unending attempts to water down any victory for wildlife." In this vein, I can't imagine what Dan and the rest of the BFC feel when they see our tax-payer's dollars being not only wasted, but literally abused as bison are chased, harassed, and persecuted all for leaving the confines of YNP. Most of the time they are harassed for being on public land that all Americans own. I can't help but think of the hypocrisy of this occurring in supposedly fiscally conservative "red states" all to benefit a small minority of people.

So, the question you might be thinking is, what can be done, or what can I do to stop this madness? Well, for starters, I haven't purchased beef for years now and in addition to ethical and environment issues, the way that bison are treated is a major reason for me — even though only a fraction of cattle that feed the nation come from the states surrounding YNP. Second, I strongly advise all readers to contribute to the BFC, or at the very least get on their email list. They send out important action alerts where you can make your voice heard and comment to decision makers to help reign in the DOL and provide bison with the respect and treatment that they should be granted as native wildlife, just like all other wild animals are afforded. It is really easy to send an email to elected officials – make your voice heard! I know one of the first things that I am going to do is send this review to politicians who should do the right thing by reading this book, and then stopping the ongoing hatred and mistreatment that bison receive. One can start by removing the DOL from having authority over bison management and allowing state and federal wildlife agencies to take over, and by providing protections to bison until ecologically viable populations are established in more areas where they are native. Lastly, I believe that every United States legislator should be given a copy of *In the Presence of Buffalo*, so they can vote with their minds and hearts, and not politics, to better protect America's last truly wild buffalo.

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Frogs of the United States and Canada (2 Volumes)

By C. Kenneth Dodd Jr. 2013. John Hopkins University Press, 2715 North Charles Street, Baltimore, MD, USA, 21218-4363. 982 pages, 180.00 USD, Cloth.

There is something irresistibly attractive to many about frogs. Perhaps it's their mechanical hopping that has appealed to us since our childhood, perhaps it's the bursting out in song by males to attract females and intimidate rivals which signals the beginning of spring in the north and/or later in the seasons before imminent rain, continuing in a succession of shifts of species into summer, and resuming sporadically in late summer and fall, with breeding in southern localities. Perhaps it is their long history back to their first known appearance of frog-like fossils from the early Triassic Period (225–245 million years ago).

Because of their position in the food chain as both an important consumer and consumed, indications of a world-wide decline in frogs has gained considerable attention in recent years. The alarm was initially raised at the first World Congress of herpetology in 1989 because of the realization when herpetologists from many countries assembled that major declines in frogs were being noted in many regions. Frogs, partly because of their annual vocalizations were conspicuous for monitoring, were soon widely promoted as “canaries in a coal mine” to monitor general environmental health. Publications burgeoned as funding increased and included new conservation-focused journals. Even in Canada, although only one frog had been recently extirpated, Blanchard's Cricket Frog, once common on Pelee Island, many other frog species are now listed as endangered or at risk by the Committee on Species of Endangered of in Canada (COSEWIC).

In North America public interest in frogs in general was focused by Mary Cynthia Dickerson in 1906 with *The Frog Book* and further nourished in 1914 by the classic life history studies by the husband and wife team of Albert azen Hazen and Anna Allen Wright. This study presented detailed treatment of identification for eggs and tadpoles, and timing of transformation and maturity from the authors' base at the Cornell University campus at Ithaca, New York. It was followed in 1932 by a similar treatment of the frogs of Okefenokee Swamp on the Georgia–Florida border plus some additional species omitted from the earlier study. In 1933 a compilation for all of North America was published as *Handbook of Frogs and Toads* by the Wrights. This was expanded in a second edition in 1942 and a third edition in 1949 blending their earlier studies with notes from their field work across North America and the rapidly growing literature. This remained the standard for the next 60 years until then 2009 publication of *The Frogs and Toads of North America: A Comprehensive Guide to Their Identification, Behaviour, and Calls* appeared which gathered the increased information on frogs appearing in continental and regional field guides.

The Frogs of the United States and Canada is the newest comprehensive contribution. The author states that it is intended as a synthesis of the published scientific (peer-reviewed) papers for these countries through May 2011. It is not a field guide to identification, for the latter the reader is directed elsewhere. In the 17-page introduction which condenses general information on frogs it is stated that “as this book is completed (April 2013) there are more than 6,900 species of frogs known worldwide with new species being described at a rapid pace”. One hundred species (10 just barely) occur north of the United States–Mexico border; 27 of these are said to occur in Canada but my own tally falls short by two. None are unique to Canada. After contrasting various morphological variations within frogs there are brief entries on anuran evolution, life history, frog conservation, etymology, and “about this book” giving account headings measurements, precision, and generalizations. The latter has very pertinent remarks on differences between authors in ways of stating variables and the often lack of consideration of regional differences in many publications. It is stressed that what appears to be a wealth of published data actually reveals a great deal of repetition, some of it inexact. It also stresses and how little is known yet about basic variations in frog natural history. Omitted, presumably as it lacks the quality control of peer review, is much of the regional information in the so-called “grey literature” of unpublished texts and theses, reports for government and private firms, natural history and herpetology club newsletters and on-line postings and status reports (although some of the later, often with sensitive data removed, and atlases, often with precise information on localities removed, are at least available on-line). The introductory material concludes with a section “For further information” which covers standard reference books on herpetology including general overviews, catalogue, management and conservation, and listing of selected internet sites and atlases, sound recordings, and professional, herpetological societies in North America.

The bulk of content (pages 1–460 volume 1 and 462–832 volume 2) is comprehensive species accounts which cover nomenclature, etymology, identification (brief descriptions supplemented with photographs of adults, eggs, tadpoles, and habitats), distribution, fossil record, systematic and geographic variation, adult habitat, terrestrial and aquatic ecology, calling activity and mate selection, breeding sites, reproduction, larval ecology, diet, predation and defence, population biology, community ecology; diseases, parasites and malformations, susceptibility to potential stressors, status and conservation. The concluding bibliography on pages

837–973 is a comprehensive synthesis of more than 4,500 references (author's count) of peer-reviewed literature to May 2011.

Throughout, the most recent studies are largely accepted which means that recent taxonomic decisions based on DNA studies replace some longstanding ones on morphological variation. For example, the abandoning of subspecies in the Green Frog, *Lithobates clamitans*, and the application of the name *Pseudacris maculata* to populations of Chorus Frogs in the northeastern portion of the Great Lakes-St. Lawrence corridor which had been formerly known as *P. triseriata* (the latter is retained for populations to the southwest). In such a comprehensive work lapsi are inevitable. Dodd himself advises the checking of original references given for verification of statements. Canadian portions of distribution maps are often poorly and carelessly done. Examples abound but particularly misleading is the creation of overlapping ranges by inclusion of *Anaxyrus hemiophrys* in the northwest corner of Ontario and *A. americanus* extended to mid-Manitoba despite the documented hybridization between these forms and their

failure to maintain separate populations whenever their ranges meet. This makes the occurrence of one within the range of the other highly unlikely. Some introgression of characters may account for confusion from the older literature. A record for *Pseudacris maculata* in the interior of Quebec is based on a cataloguing error. In the distribution map for *Hyla chrysoscelis* it is omitted from Manitoba though its presence is noted in the text. A text oversight is that a hybrid documented from the range overlap zone in Alberta between *A. hemiophrys* and *A. boreas* is mentioned in the account of the former but omitted from the latter.

The price and the sheer extensiveness of the documentation may put this effort beyond the budget or needs most naturalists but it is a must investment for any serious researcher on any aspect of North American frogs or any institution which includes research on them in its mandate.

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Frogs of the United States and Canada (2 Volumes)

By C. Kenneth Dodd Jr. 2013. John Hopkins University Press, 2715 North Charles Street, Baltimore, MD, USA, 21218-4363. 982 pages, 180 USD, Cloth.

In the preface to this mammoth two-volume set, the author quotes a New Zealand saying: "fact: the survival of the Earth depends on frogs". Unfortunately, the threats to these species continue to grow. Understanding these threats has never been more important and this publication summarizes the current scientific knowledge on the 100 species found in North America.

The book begins with an introduction to the biology, evolution and conservation of frogs. The bulk of the book provides detailed species accounts. The accounts follow a thorough and standardized format that makes locating information very easy: etymology (of the species name); nomenclature; identification; distribution; fossil record; systematics and geographic variation; adult habitat; terrestrial and aquatic ecology; calling activity and mate selection; breeding sites; reproduction; larval ecology; diet; predation and defence; population biology; diseases, parasites, and malformations; susceptibility to potential stressors; status and conservation. Each account also usually includes colour photos of the adult, tadpole, eggs and breeding habitat. The photos are good to very good, in general. Each species account also has a black and white distribution map. The accounts vary in length depending upon how much information is available for North American populations (Dodd excluded studies conducted south of the United States as tropical populations may differ in their life history). The account for the Rio Grande Chirping Frog (*Eleutherodactylus cystignathoides*) is only three pages (including one photo and a distribution map) but some accounts are more than 10 pages long.

Overall, the quality of the text is extremely high. Dodd has synthesized the scientific literature on North American frogs published up to May 2011. The bibliography consists of over 4,500 titles and is over 130 pages long. The book is more than just a summary, as Dodd has also critically examined that literature. This is a key issue as many "species" are now recognized as diverse species complexes. For example, the Northern Leopard Frog (*Lithobates pipiens*) was once considered an extremely wide ranging species with a high degree of phenotypic variation, while it is now considered a complex of about 20 different species. Hence Northern Leopard Frog papers published before the early 1970s may be about a different species. In the Northern Leopard Frog account, Dodd identifies papers where there is confusion over the study species. Of course no publication is perfect. Dodd states that all references in his book "have been examined for accuracy of citation and content" (p. xxiii). I have no doubt he did examine every paper, but the occasional citation error still occurs. For example, Catherine Bevier is the lead author of two cited papers on Mink Frogs (*Lithobates septentrionalis*). In the text she is variously referred to as Bervien and Bervier as well as by her correct surname. And in the bibliography the papers are incorrectly attributed to Bervier.

From a Canadian perspective, there are some areas that could have been improved. The book states that only Blanchard's Cricket Frog (*Acris blanchardi*) is listed by the Committee on the Status of Endangered Wildlife in Canada. This overlooks a number of other

listed species. Both the text and distribution map incorrectly indicate that Canadian Toads (*Anaxyrus hemio-phrys*) are found in extreme western Ontario. Although the text correctly indicates that Cope's Gray Treefrog (*Hyla chrysoscelis*) occurs in Manitoba, the distribution map omits this. Similarly, for the Mink Frog, the text correctly states that it is found on Cape Breton

Island, but the map shows that it is not found there. Nonetheless, these are fairly minor errors considering the vast scope of the book and overall, this is a major contribution to frog biology and conservation.

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Enter the Realm of the Golden Eagle

By David H. Ellis. 2013. Hancock House, 19313 Zero Avenue, Surrey, BC, Canada, V3S 9R9. 496 pages, 60.00 USD, Cloth.

When David asked me to write a short reminiscence about an experience with a Golden Eagle and to provide a photograph, I cheerfully complied. I expected in return a small, simple, uncomplicated book. Wow! What a surprise! In the mail came a massive, 4.7 pound, hardcover, 496 page book with 18 chapters and an epilogue. It contained over a hundred stories by 48 authors from 20 countries, superb colour photographs of beautiful eagles and gorgeous scenery by 21 photographers, and paintings by 15 artists. Based on world-wide adventures that include Siberia, Mongolia, South America and Scotland, David Ellis wrote 60 of the 93 sub-chapters himself.

Published by Hancock House, and sold by Buteo Books and the American Birding Association, this tome was printed superbly in South Korea. David's Introduction explains his approach: "Eagle researchers tend typically to be terse, having been bruised and battered into this mold by reviewers and editors. They wrote less, so I wrote more. ... In this volume, I place the eagle within reach ... Welcome to the realm of the Golden Eagle. May you never escape its grasp." Readers will learn about the major eagle writers of all time. References are provided at the end of each chapter.

For the reader's interest, David includes a biographical note about each contributor. He tells a story about Al Harmata, the six foot five, 245 pound giant who lost his left leg and left arm in Viet Nam. Imagine the consternation decades later, on a trail in Wyoming, when Al saw a large female Golden Eagle perched in a sage bush and yelled "STOP THE TRUCK." The tech driving the truck said "You can't catch that eagle." But Al hopped on one leg (he cannot run) between the five- to seven-foot high sage plants, his empty sleeve flapping in the breeze. Al had noted that the large female eagle had a full crop, was in a confined space, and there was no wind. To the tech's astonishment, Al emerged with a healthy, wild Golden Eagle cradled in his right arm, ready to be banded.

David also tells of Adam Watson, only 13 years old and holidaying in Deeside, Scotland in 1944, who cycled to meet the famous Golden Eagle author, Seton Gordon. Gordon took him on a long hike to show him the eyries he had been watching since the early 1900s. In subsequent years the two of them compiled 70 years

of Golden Eagle observations.

Many facts are of biological interest. David visited a Golden Eagle nest that was seven meters deep in Sun River, Montana. Another nest in Montana contained 35 unweaned ground squirrels.

Three of a number of once-in-a-lifetime experiences are worthy of special mention. Maurice Broun, the first warden at Hawk Mountain, Pennsylvania, observed a Golden Eagle pluck a hawk, in this rare instance a Red-shouldered Hawk, from the air in migration. Martin Tjernberg in Sweden watched a Golden Eagle pursuing a hare; when the hare jumped four feet in the air, where the eagle sank its claws into it and held on for twenty seconds until the hare was dead. Herman Lovenskiold, in Norway during the "lemming irruption year" of 1891, found three almost fledged eaglets and two downy young eaglets in the same nest; several explanations are offered.

Rarely, a prey animal can kill an eagle. A Golden Eagle in Scotland captured a stoat, lifted it in the air; then the eagle dropped suddenly to the ground as if shot. The stoat had severed arteries in the eagle's throat causing its death in the air. In Scotland a Golden Eagle captured a Wild Cat, *Felis sylvestris*, and carried it upwards for several hundred feet before the mangled corpse fell to the ground. The next day the eagle was found nearby, disembowelled by the cat's claws or teeth while airborne.

Some eagle watchers have shown interest in the many-centuries-old Native American practice of digging a pit to catch eagles to obtain ceremonial head-dress feathers. A Hidatsa Indian would sit for hours or days cramped in a pit, with bait consisting of a rabbit and a deer lung above him; when the eagle pounced, the First Nations man would raise each hand quickly to grasp both legs of the eagle simultaneously. William S. Clark wished to test this firsthand and flew from New Jersey to Los Angeles to try his luck in the pit built for this purpose north of the city by Peter Bloom. Clark caught two Golden Eagles in one session.

Beware; the reader is exposed to the gory details of kills. I will mention only a few examples. Some eagles in Scotland learned to drive large prey over a precipice, to be consumed at the bottom of the valley. Eldon Bruns in Alberta watched an eagle dig its talons into the back

of a 70-pound pronghorn fawn for 20 minutes until the fawn died of exhaustion and shock. Golden Eagles in a Himalayan valley attacked demoiselle cranes, but only 4 of 67 attacks were successful. Ellis was particularly interested in the use of Golden eagles in Mongolia as a treasured falconry bird which can kill a wolf eight times its weight.

I have minor quibbles. David's enthusiasm causes him to describe the actions of three **captive** eagles across the length of 19 subchapters, somewhat excessive for my fancy. Because of the weight of the book,

older people may find it more comfortable to read the book a chapter at a time, with it propped up on a table. David enlisted dedicated proof-readers but apparently no Canadians were involved, since the French word *coulee* is spelled *coolie* on page 378.

Enter the Realm of the Golden Eagle will make a fine gift for a falconer, eagle bander or obsessed eagle watcher. For most, the illustrations alone will be worth the price of this already subsidized book.

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Looking for the Goshawk

By Conor Mark Jameson. 2013. Bloomsbury Publishing Inc., 385 Broadway, New York, NY, USA, 10018. 368 pages, 18.99 GBP, Cloth.

I opened this book with some trepidation. Many books on a single species are written by scientists who have spent years collecting a mountain of minute details. These they pour into the book, turning it into a dry read. I usually wish they had put more effort into an interpreted summary. This book is not like that at all.

Instead this is about a passion for one species, the Goshawk in the United Kingdom. This passion takes in everything that relates to this predator – literature, art, taxidermy, falconry, habitat and, of course, the bird itself. It equates to me having an infatuation with Ross's Gull in Canada (our gull population is about 100 pairs while the UK Goshawk numbers about 400).

Conor Mark Jameson is the author of many books and scripts. He is a columnist and writer for nature magazines and has worked in conservation for many years. He is stationed at the Royal Society for the Protection of Birds' headquarters in Sandy, Bedfordshire. In this book Jameson chronicles his search for this elusive bird. It recounts his passion with antique books on natural history, and how they treat the Goshawk. He visits the locations where these authors lived and explored. He investigates the history of the bird's demise in Great Britain. He visits their habitats and talks to many experts.

Sightings of Goshawks in the UK are treated with extreme scepticism by the "experts". I compared our problems of identifying Sharp-shinned and Cooper's Hawks with Goshawks and the British birder's trouble with Eurasian Sparrowhawks and a Gos. They are similar and some of the identification differences are the same. I think their doubt stems from a lack of familiarity. We see Sharp-shinned and Cooper's Hawks with regularity and Goshawks occasionally. Using hawk watch data, for every Goshawk we see we should observe two dozen Cooper's and 200 Sharpshins. I have seen at least one Goshawk a year in the last few years. So they are not common, but we do see them and we identify the other accipiters regularly. It is telling that the author quotes several visitors from Europe, where

they see Goshawks regularly, with seeing this bird species near Sandy. Yet the author hesitates to identify many of his local raptor sightings.

The writing style is very far from dry and is often poetic. Reading his descriptions of the English countryside was, for me, nostalgic. It is delightful to join him as he wanders to different, picturesque localities. His enthusiasm for books, particularly classics, reflects my own. His comments on falconry and taxidermy are responsible yet understanding. But it his endearing passion for this one bird that shines through.

I read with growing impatience until, a third of the way through the book, he finally sees a Goshawk — in Berlin. After the last war the allies confiscated all guns. As a result there was a rise in some bird populations, notably birds of prey. Goshawks now nest in a number of city parks, devastating the local populace of pigeons and crows. Is there a lesson for the City of Ottawa here?

So who should read this book? It is not aimed at the professional researcher. Its rambling style does provide a lot of information on the biology of this bird. It is, however, buried in musings that highlight the author's passion (actually it seems closer to an obsession). The author wanders through the English countryside with delightful, lyrical descriptions, gives detailed accounts of discussions with friends and muses on the content of books. These writings he ties, often with a tenuous connection, to Goshawks. Also buried in the text are some very interesting conservation issues and conundrums. (Would a number of species really be extirpated if the grouse and pheasant hunts were eliminated?). They highlight, not just the major impacts of humans, but a lot of more subtle effects. I believe this is a book for the enthusiastic naturalist who likes to sit by the window or fire and enjoy a relaxing time, while following their interest in the environment and sharing this man's zeal for the magnificent Gos.

On a personal note; a Goshawk was one of the very few creatures to attack me in the wild.

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Rare Animals of India

Edited by Natarajan Singaravelan. 2013. Bentham Science Publishers, P.O. Box 446, Oak Park, IL, USA, 60301-0446. 280 pages, 36.00 USD, electronic.

This is the first time I have reviewed an e book. I got my copy by contacting the publisher (<http://bentham.science.com/ebooks/a-z.htm>). I went to their site and clicked a Login button that led me to a 'Download' button where I was able to save the pdf file of the book (25 Mb file size) to my computer. The normal download is subject to a one time purchase/fee for the book.

This book has twelve chapters covering twelve animals or groups of animals. It does not cover the "poster animals" — Bengal Tiger, Asian Elephant and Greater One-horned Rhinoceros. The animals in this book are Caecilians, Reptiles of Western Ghats, Agamid Lizards, Indian Gharial, Forest Owlet, the Vultures, Shortwings, Salim Ali's Fruit Bat, Hispid Hare, Bengal Marsh Mongoose, Hoolock Gibbon and Snow Leopard. The book is fascinating in two ways.

The first way is the content about the animals. The first chapter on Caecilians was fascinating for me. I know little about these animals so most of the text was new information. I find it strange that some amphibians look like earthworms or snakes and they live mostly underground. It seems there are 200 or so species of Caecilians, of which only 36 species known from India. My guess is that much of the country is too dry. Most of these live in the Kerala Region of the Western Ghats, the area covered in this book. The text provides an insight into the lives of these weird creatures and, of course, how to identify a dozen or so Indian species. There are photographs of both the animals and their habitat. The raging question that built as I read was how do I find one. The authors cover this issue, but it is not a tempting process — you must dig and did and dig ...

The chapter on Endangered and Enigmatic Reptiles of Western Ghats covers two species of turtles, five of geckos, 25 lizards and 68 snakes. This is far too much for one chapter and many species are included as part of a checklist only. Some of this is annotated and a number of species have photos (a few as road kill!). All of this is helpful, but I would like to have seen more.

Agamid Lizards covers only three of the 48 Indian agamid species, but this coverage is more satisfying. The text provides good information on the species and the range maps are most helpful.

Last year I was delighted to see seven Hoolock Gibbons and one Slender-billed Vulture (more later). The call of the Hoolock Gibbon is one of the great songs of the wild. This year, when I return, I hope to see the Indian Gharial. This crocodile has long jaws to use with its fish diet. Sadly it has declined dramatically and now needs a special effort to find it. The authors have provided a portrait of this poor beast and the reader will learn much about Gharial life. Faced by numerous threats the future looks sad for an animal with a 100 million-year ancestry. Captive breeding and re-intro-

ductions have had poor success as the problems of habitat loss etc. have not been solved.

The Forest Owlet was considered extinct for 113 years until found by two American ornithologists in 1997. The authors detail their search for this bird and summarise the known knowledge. The most bizarre reason I have heard about for the destruction of owl eggs is to take one to a witch doctor, who coats it in soot. This egg is kept under a pot and the next day a number is divined in the soot. This is a lucky number that the gambler uses for the day.

Shortwings, also known as Blue Robins, live in high-elevation forests or sky islands in the Western Ghats. Like many birds in limited habitats they are in trouble. Among the results of this study the researchers found several under storey birds, including Shortwings, were infested with ecto-parasites.

Salim Ali's Fruit Bat was identified in 1972 from a 1948 specimen. The current research has shown this cute mammal is actually more numerous and widespread than originally thought. It is still a rare bat and needs to remain on the endangered list.

The Hispid Hare disappeared from 1956 to 1971. This author's intent was to find out more about this elusive beast and get an idea of population density. This he did by counting droppings and attempting to catch specimens. For all his efforts he saw only 13 and netted two.

The Bengal Marsh Mongoose is one of those species that have been split from a larger population (in this case from the Small Indian Mongoose). This split is not accepted by all authorities. Comparing photos, it is hard to see a difference. The creature I saw in the dry Kolkat Botanical Gardens last year, I am still convinced was a Small Indian Mongoose. The author says the Bengal Marsh Mongoose was fairly common in Salt Lake City (a suburb of Kolkat, now mostly shopping centres etc.), but habitat destruction has made them rare.

India is home to nine species of vultures which have been venerated for centuries. They are the most efficient scavengers and their drop from more than 100 million to the low thousand has caused major environmental and social consequences. The decline is blamed on the use of veterinary drugs such as diclofenac. Slender-billed Vultures now only number around a thousand, so I was happy to see my single bird. The authors explain the biology of vultures and the work being done to save them. The efforts to census the existing populations, saving orphans, breeding and re-introduction programs are covered in some detail.

The other way this book is interesting is the language. I do not believe that I misunderstood any of the author's messages, however the text is full of errors.

There are numerous examples of strange word orders (e.g., Thus, the egg hunters (especially tribal people) are regularly visited those identified areas for easy collection of delicious eggs. I am sure this means — Thus, the egg hunters (especially tribal people) regularly visit the known areas to collect the (delicious) eggs).

Many readers will find some of the language technical, which is fair, but I sometimes felt the love of large words went too far. For example, using anthropic (the anthropic principle is the philosophical consideration that observations must be compatible with the conscious life that observes it) when the word anthropogenic makes more sense; or pupation (To become a pupa.) instead of population. Some words seem to be simply mis-typed like bail (property pledged to a court) instead of bait. Others are correct words in the wrong place such as “it’s wider (than what?) throat” instead of “its wide throat.” Then there was the classic “poisonous or non-poisonous snakes and frogs” which I think means “venomous or non-venomous snakes and poisonous or non-poisonous frogs.” Some words are purely Indian and are not familiar to non-Indians

(Bands — body of water ?, Goonch — a catfish, beel — lake or is it a flooded paddyfield?). It seems the word tribal (plural tribals) is used in India as a noun as well as an adjective.

The text is often repetitive, sometimes in the same sentence and generally in the same paragraph. An example is “Recognised easily by its extremely long and slender beak-like snout” and “easily distinguished ... by the long and narrow snout.” The use of animal names is inconsistent. Sometimes the common English names are used with all words capitalized, or partially capitalized or all in lower case. Sometimes only the scientific names are used.

Despite the editing problems this is a valuable contribution to our knowledge. Those of us who have been privileged to visit India once, always want to return. Amid the masses of humanity you can still see wildlife, and this book shows the value Indians place on their heritage. It is well worth reading for visitors and residents of this fabulous country.

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BOTANY

The Illustrated Encyclopedia of Trees. Second Edition.

By David More and John White. 2013. Princeton University Press, 41 William St., Princeton, NJ, USA. 08540. 832 pages. 49.95 USD, Cloth.

What an interesting book this is, both beautiful and enigmatic. Not only that, unusual for a tree book, it includes discretely tiny animals. The North American edition of a European book, it is built around David More’s quest to record with paintings all the tree species found growing in British Isles. Of course, that would constitute some native species, but very many more imported by collectors from elsewhere. As John White explains (assuming he is the author of all the text), while North Americans are blessed with a huge diversity of tree species, the differing ice age glacial patterns of the two continents mean that Eurasia has many fewer species but very wide east-west distributions. Perhaps to make up for it, Europeans have been eager plant collectors, so Britain and Ireland now have more diversity of tree species than any other similar-sized, temperate land mass. A good section of the introduction is devoted to the plant collectors of past centuries.

The book covers trees of the northern temperate zone, more or less, including species from all around the northern hemisphere plus a few from the south that can survive in the north. The scope is really defined by what can be grown successfully in the British Isles. There is a heavy focus on growing trees ornamentally, and cultivars are covered along with species, subspecies and varieties. Here is where the enigma comes in. I can’t decide if this book is something that is trying to be

something else. I kept looking for some sort of further explanation in the text, but never found it. There is some kind of missing link to add more sense to the reasoning for a North American edition. It looks like it’s going to be an encyclopedia of wild trees in their native landscapes, or, at least, that is what I was expecting. However, it is really aimed at people who are selecting and growing trees. Or is it? Maybe it really is legitimately meaning to straddle both. Maybe it’s just my North American perspective that wants a dichotomy. Perhaps if I’d lived my life in a place like England where most of the tree cover had been heavily managed and modified by humans for so much longer, the distinction would be irrelevant. Maybe it is irrelevant anyway. In North America I have the idea that there are urban forests composed of some native species and many not native, and many naturalized. Then I think there are wild forests where the species composition, at least, has not been manipulated. It would seem strange to blend the two into one book. But where is that pure, wild forest, really? All over North America, forests (including those lower than your ankle) have been changed by forestry, earlier clearing and other human influences.

The other part of the enigma comes from my librarian-like feeling that all books must be placed within a known category. This one is called an encyclopedia, and I’ll grant it that. But somehow the basis for what

trees are included is not systematic enough for me to feel really comfortable with 'encyclopedia'. It is a more like a curated collection. Really, it is a huge arboretum tucked between covers as long and broad as a sheet of letter paper and as deep as, perhaps, an old-fashioned pencil eraser. It is not a field guide (it doesn't claim to be) where you know you are getting wild, native trees, at least for the most part. It is not a regional overview based on natural geography. It is certainly much more than your average guide to trees and shrubs in horticulture. It is nothing like the manual for growing woody plants in my library, either, for that book's purpose is 100 percent guidance and instruction. This book's purpose is ultimately, I believe, to stun one with the wonder of trees, which it does.

To give an idea of the details provided for each tree species, here is what is included in the account for Eastern Hemlock (*Tsuga Canadensis*): it's appearance including how it differs in the wild and in cultivation; its native range; where it is hardy, both latitude and altitude; the many cultivars developed from the species since 1736; it's expected height in 10 years, 20 years and eventually; hardiness given as a percentage of tolerance to frost ranging from 0% at the freezing point to 100% at -40 degrees C or F (-40 being the point where Celsius and Fahrenheit are the same); a number code indicating choice considerations for gardens and where applicable a number code for the quality of the wood for use.

The illustrations are finer than any I've seen; certainly more realistic and precisely captured than in any of the tree books in my library. They are gorgeous and comprehensive, with lots of time given to small details,

cross-sections of conifer needles, summer and winter views, close ups of leaves, leaf scars and buds, twigs, cones, fruit, bark, flowers. This is unquestionable talent driven by passion.

The secretly charming little bit I didn't even notice until I'd looked through the book a few times is the use of life figures for scale. These range from birds (lots of magpies and hawks) to weasels, foxes, deer, pet dogs, cattle and people. For a few moments I forgot about the trees and flipped through looking for the tiny creatures. They're not on every page, and I admit to being disappointed when there isn't one.

Like in some arboreta, the species are arranged taxonomically. There are no keys, just titles and a table of contents filling the role of sign posts. To use this book for identification purposes you will first need some idea of what type of tree you are looking at, and then you will have to browse. The introduction makes a solid read on its own, with lots of interesting information about tree distribution, collection and growing.

I recommend this book for any tree lover, especially one who hankers to roam, tree by tree, across the northern temperate world. If you took the time to gaze each day at one of its pages, you would have a handy substitute for getting out of doors to look at live trees. If you are plotting your own arboretum, or just to plant a new tree in your yard or garden, this book will help you too. If you've got the cash, I suggest the hardcover version, because it's a big book. The Princeton University Press online catalogue only showed the cloth cover version when I checked today (October 2, 2013).

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OTHER

Walking Wild Shores: Portraits of the Natural World

By Kevin Winker. 2013. Two Harbors Press, 212 3rd Avenue N., Suite 290, Minneapolis, MN, USA, 55401. 353 pages, 16.95 USD, Paper.

This is a nicely-written collection of travel tales and adventures based on the author's experiences in mostly wild areas, both in the line of work and of living in Alaska. As Curator of Birds and a professor at the University of Alaska Museum of the North, Kevin Winker has had plenty of opportunities to find himself in out of the way places and on perilous edges. His recounting does a service to the armchair field researchers amongst us as well as those who might enjoy hearing of someone else's trials and joys similar to their own. Many chapters evoke really wild, natural places complete with dramatic weather and physical conditions. It is the kind of book you might take one chapter at a time, when you want a change from your day-to-day, whatever it may be.

Most chapters are stories of time spent in the field, from the Aleutian Islands to Mexico, Singapore and

Siberian Russia. Of course, as it's the reason behind most of his travels, Winker leads us into the objectives of his research, mainly studying patterns and processes of avian evolution. To that end, collecting sufficient samples of birds for study, mostly by shotgun, recurs often from beginning to end of the book. This includes an account of trying to collect an elusive Pacific Wren on the Aleutian island of Amlia. It reads like a true hunting pursuit, except the quarry is so tiny. Think of the wee, flitting wren, seemingly taunting from impossible cliffs and crevices, popping out and then disappearing, only to emerge for a split second somewhere else. It might be the most challenging chase in the book. Collecting animals that others seek for viewing pleasure does put one in a sort of unfriendly spotlight sometimes. Winker offers an explanation of the importance of maintaining and continuing bird collections

for ornithological study and conservation and at the end of the book offers a reading list on the topic.

Daily life chapters have us perching on ledges in roaring river canyons using dip nets to nab salmon speeding by, or driving a car in extremely cold weather when the doors don't want to close and really nothing wants to move at all. We took a tour through the frantic pace of summer work, both in the office and out, necessary and also made possible because of long summer days and long winter nights. We also glimpse some of the more unusual personalities populating Fairbanks.

Field work and travel headaches appear often; they're all part of the lifestyle. You might be surprised to learn that, although Alaska is very close to Siberia, someone wanting to travel from Fairbanks to Novosibirsk could more likely be routed through Minneapolis, Amsterdam and Frankfurt. Have you ever had to empty a cylinder of liquid nitrogen into a drainage ditch at 2:30 in the morning before travelling to the airport for your flight home from Singapore? Then, you have to worry about your specimens staying frozen

while you endure delays of many connecting flights and border officials who don't want simply to accept your many permits at face value. How about having to modify your collection plans because you couldn't get shotguns in Mexico on account of the Zapatista rebellion in Chiapas? And then there's all that proposal writing and applying for permits, permits, permits. And then, does anyone ever go for a road trip in Alaska without at least one spare tire? No. But what if your one spare is flat too? That stuff you buy in a spray can to stop the leak in a flat tire really works ... for a while.

If you enjoy reading about all the interesting things that can happen to someone else (and who doesn't enjoy that, really) and would like a dose of gorgeously-conveyed wildness, you might have a look for this book. It could be just the thing for a current or future ornithologist or, indeed, an armchair biologist, on your gift-buying list.

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The Efficiency Trap: Finding a Better Way to Achieve a Sustainable Energy Future

By Steve Hallett. 2013. Prometheus Books, 59 John Glenn Drive, Amherst, New York, NY, USA, 14228-2197. 337 pages, 19.00 USD, Paper.

"The world is teetering on the brink of disaster, the people with their grip on economic power are pushing us faster toward the edge of the cliff, and we are all being swept along," is a quote from the middle pages of the book and sums up Hallett's thesis. Like his first book (with John Wright), *Life Without Oil: Why We Must Shift to a New Energy Future* (2011), this book is a record of the research on global use of energy, a report of the diminishing supplies of oil, gas and coal and the evidence which we have for these conclusions. In addition Hallett examines the ideology of increasing production of all things as a way of measuring success. Increasing production in resources, food, gross domestic product and even population are measured to prove our society is doing well or not keeping up with its goals. It is true that we have gotten better at what we do in business, medicine, agriculture and high-tech manufacturing as time has passed. Engines have become more efficient using less fuel, houses use less energy to heat and cool, and appliances use less energy to accomplish their task faster. The increase in efficiency has regrettably been accompanied by millions of more cars on the road, each with better energy consumption, more and bigger houses using more heat and cool, and many more refrigerators, washing machines and dishwashers providing more convenience as we get busier with the same homes, travel and consumption. The bank of energy is steadily depleting as we plunge on with expectations of ever-increasing production.

Hallett tries to show how progress in human history has always had a growth imperative. Growth and in-

creased efficiency are never the means to use less of a resource, but instead increases the use of the same resource because it can be used more widely to do more things. A steam engine which was invented to pump water from coal mines became the steam-powered paradigm of industry, transportation and more efficient extraction of coal to fuel it all. The modest increase in coal production envisaged in a better pumping system gave rise to an exponential demand for coal as the engine became the source of power for so many functions. The conventional wisdom telling us fossil fuels can be saved if we consume them more efficiently is similarly ill-conceived as we increase production of more efficient vehicles with more transportation costs for assembly and distribution, and more people using them to drive further.

In a dooms-day prediction Hallett predicts that the economic collapse, the final drain of the oil fields and the after-peak time of natural gas will all come together in the 2030's. As warning signs we should look at our personal debts, housing, employment, food, water, physical security, and transportation. Each of these has increased in its own way but the capacity of each to collapse in the current pattern of resource use has also grown. Most parts of nature exist in equilibrium but not in sustainability. Things grow and die, and continents and their ecosystems change but not with unaltered life to all of their members. Organisms which are best adapted to their environment are able to exist for the longest time in that same environment. Different sustainable agricultural practises like the Amish refusal

to use petroleum-powered equipment on their farms, or the efficiency of small acreage farms of some market gardeners as opposed to large acreages which can only be managed with large fuel-intense equipment are given as modern North American examples of counter-cultural change. Each of these is achieved only with strong community support, family identity and common work ethic to sustain the land production. Increasing food production by growing vegetables in areas like downtown Detroit which was abandoned by homeowners or the change of agricultural production of Cuba

after the collapse of the Soviet Union are both examples of how scarcity has given rise to a different kind of less efficient, non-growth potential. When a community tries to change, the change is slow in human terms. When we are caught in a changing world the change will come upon us whether or not we will it. Hallett's book is a reminder that the change is upon us and our only response can be to change with it. He encourages us to change sooner than later.

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned

Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros, AUD Australian Dollars.

ZOOLOGY

Rare Birds of North America. By Steve N. G. Howell, Ian Lewington and Will Russell. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 448 pages, 35.00 USD, Cloth.

The Crossley ID Guide – Britain and Ireland. By Richard Crossley and Dominic Couzens. 2013. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 304 pages, 27.95 USD, Flexibound.

* **Into the Night – Tales of Nocturnal Wildlife Expeditions.** Edited by Rick A. Adams. 2013. University Press of Colorado, 5589 Arapahoe Ave., Suite 206C, Boulder, CO, USA, 80303. 206 pages, 26.95 USD, Cloth, 21.95 USD Electronic Book, 9.99 USD, 30-day Electronic Book rental.

OTHER

* **The Once and Future Great Lakes Country - An Ecological History.** By John L. Riley. 2013. McGill-Queen's University Press, 1010 Sherbrooke West, Suite 1720, Montreal, QC, Canada, H3A 2R7. 516 pages, 39.95 CAD, Cloth.

News and Comment

The Canadian Herpetologist (TCH) 3(2), Fall 2013

The Canadian Herpetologist (TCH) is a publication produced twice each year by the Canadian Association of Herpetologists and the Canadian Amphibian and Reptile Conservation Network.

CONTENTS: Executive Members of Societies — Instructions for Authors — Editorial Notes — Meetings — Feature Articles: The Importance of Species Occurrence Data and Herpetofauna Atlases in Canada *by J. Crowley*; IMPARA Nomination: Pemberton Valley, B.C. *by L. Anthony*; Propriétaires agricoles riverains et tortue des bois : des résultats probants *by M. Lelièvre et C. Robidoux* — Field Notes: Herpetofauna Observed During the Royal Saskatchewan Museum Bioblitz *by L. Heisler, A. Fortney, N. A. Cairns, A. Crosby, C.*

Sheffield and R. Poulin; Severe multiple kyphosis (spinal kinking) in an Eastern Foxsnake (*Pantherophis gloydi*) *by D. Brazeau, P. Catling, M. Ciancio, A. Whitear and C. Davy* — Book Reviews — Thesis Abstracts in Canadian Herpetology: **Davy, C. M.** Ph.D. 2013. University of Toronto, Toronto, ON. (Supervisor: B. Murphy). Conservation Genetics of Freshwater Turtles. — **Leung, M. N.** M.Sc. 2012. University of Calgary, Calgary, AB. (Supervisor: Anthony Russell). Phylogeography of the Greater Short-Horned Lizard (*Phrynosoma hernandesi*) in Alberta. — Recent Publications in Canadian Herpetology — News and Announcements — Membership Forms: CARCNET.

Upcoming Meetings

2014 Meeting of the Association of Field Ornithologists and Wilson Ornithology Society

The joint meeting of the Association of Field Ornithologists and Wilson Ornithology Society to be held 29 May – 1 June 2014 at Salve Regina University, Newport, Rhode Island. Student travel awards dead-

line is 15 January 2014. Abstract and early registration deadline is 15 March 2014. More information is available at <http://wos.salvereginablogs.com/afo-wos-meeting>.

American Society of Mammalogists Annual Meeting 2014

The 94th annual meeting of the American Society of Mammalogists to be held 6–10 June 2014 at the Renaissance Oklahoma City Convention Center Hotel and Cox Convention Center, Oklahoma City, Okla-

homa. Registration opens 15 November 2013. Abstract submissions will open on 1 February 2014 and close on 1 March 2014. More information is available at <http://www.dce.k-state.edu/conf/mammalogists/2014>.

The Ottawa Field-Naturalists' Club Awards for 2012, Presented April 2013

ELIZABETH ZURBRIGG, IRWIN BRODO, JULIA CIPRIANI, CHRISTINE HANRAHAN AND ANN MACKENZIE

On April 20th, 2013 members and friends of the Ottawa Field-Naturalists' Club gathered at the Club's Annual Soirée at St. Basil's Church in Ottawa. Awards were given to members and non-members who distinguished themselves by accomplishments in the field of natural history and conservation, or by extraordinary activity within the Club. In particular, protection of natural features and landscapes, butterflies and their con-

servation, management of the Club's scientific journal, Fletcher Wildlife Garden efforts, turtle research and conservation, sand dune restoration, and nocturnal micromoths are all in evidence among this year's winners. Short versions of the following seven citations for those who received an award were read to the members and guests assembled for the event.

Honorary Member: Dr. J. Bruce Falls

This award is presented in recognition of outstanding contributions by a member or non-member to Canadian natural history or to the successful operation of the Club. Usually people awarded an honorary membership have made extensive contributions over many years.

The ideal Honorary Membership reflects the three elements of the OFNC's mandate, the investigation of natural history, documentation of original research, and the appreciation and protection of important Canadian natural landscapes. The achievements of Dr. Bruce Falls fully embody all of these important characteristics.

Bruce Falls is a lifelong southern Ontario naturalist and eminent zoologist who has conducted and directed ground-breaking research into a variety of fields (notably breeding bird biology) during a lengthy tenure at the University of Toronto. This achievement is reflected in the establishment of the J. Bruce Falls Scholarship in Ecology and Evolutionary Biology. The web page information on that scholarship summarizes his academic achievements:

"...besides undergraduate teaching he supervised the research of 36 graduate students and five post-doctoral fellows. He was an author of over 100 scientific publications. Much of his research took place at the Wildlife Research Station in Algonquin Park, and some at the Delta Field Station of the University of Manitoba. Helped by his wife Ann, also a biology graduate of U of T, he conducted a 36-year study of small mammal populations in the Park. Fluctuations in abundance were strongly influenced by weather and tree seed crops and in turn affected the numbers of predators.

Dr Falls' main interest was in bird research. He was a pioneer in the study of bird song and its relation to territorial behaviour, basing his findings on field experiments. ... Dr. Falls is a member or fellow of several scientific societies and a past-president of the

Society of Canadian Ornithologists". (http://www.eeb.utoronto.ca/about-us/support_us/ugradschol/usfalls.htm)

Always a keen naturalist and especially active as a birder in the Toronto area, Bruce Falls became involved in conservation organizations at an early age. He was heavily involved in the Federation of Ontario Naturalists (now Ontario Nature), initiating the FON's nature reserve program as a Director and serving as President in 1962-1963.

He applied the experience gained in development of the FON's reserve system to the national scene, being instrumental in the establishment of the Nature Conservancy of Canada, which had secured the protection of over 1 million ha of natural lands in Canada to the end of 2012, a year which also marked its 50th anniversary. (<http://www.natureconservancy.ca/en/what-you-can-do/learn-more/the-ark/champions-of-conservation/j-bruce-falls.html>).

A summary of his extraordinary breadth of conservation activities is included in the biographical material in his file at the University of Toronto Archives:

"...membership in the Federation of Ontario Naturalists (director, 1946-1974; president 1962-1964; and chairman of Nature Reserves Committee, 1965); scientific advisor to the Ontario Waterfowl Research Foundation, 1960-1968; trustee (from 1962) and chairman (1971-1974) of the Nature Conservancy of Canada; member of the Conservation Council of Ontario (from 1962), Canadian committee of the International Biological Programme (conservation sub-committee member and co-chair of the Ontario panel, 1968-1974), member from 1969 at various dates of the advisory committees of the Ontario Ministry of Natural Resources on nature reserves, Mincing Swamp and the Backus Tract; honorary director from 1970 and director in 1989 of the Long Point Observatory, director from 1975 of the Owl Rehabilitation

Research Foundation, member from 1981 of the Canadian Council on Ecological Areas, member of the management committee (1981-1987) and chair (1983-1987) of the Atlas of the Breeding Birds of Ontario, and member of the Ontario Rare Breeding Program (chair of management committee, 1989)". (<http://utarms.library.utoronto.ca/researchers/james-bruce-falls>)

The Club is proud to offer Honorary Membership to Bruce Falls to recognize his immense contribution to the investigation, documentation and protection of natural features and landscapes in Ontario and throughout Canada.

(Prepared by Eleanor Zurbrigg, based on material from Dan Brunton and Francis Cook)

Honorary Member: Peter W. Hall

This award is presented in recognition of outstanding contributions by a member or non-member to Canadian natural history or to the successful operation of the Club. Usually people awarded an honorary membership have made extensive contributions over many years.

Peter Hall is an outstanding naturalist, whose interests range far and wide, encompassing in particular, birds and butterflies. It is the study of the latter which has occupied a good deal of his time, and he is certainly best known for his expert knowledge on butterflies and their conservation, about which he has spoken and written widely. Peter is very generous with his time, always willing to help with questions about butterflies, and to share his knowledge with others.

Peter was employed for many years by Agriculture and Agri-Food Canada (AAFC), first as a communications writer, editor, and later as Acting Director General, then as a senior executive in the areas of communications, publishing, strategic planning, and administration. However, conservation has always been central to Peter's life, and in 1999 he began a decade of working exclusively in this area. From 1999 to 2000, he was the National Director of the Canadian Environmental Network in Ottawa, the umbrella group for 600 Canadian environmental NGOs. Between 2000 and 2004, Peter was Executive Director of the Federal Biodiversity Information Partnership, coordinating biodiversity information management in Canada. From 2004 to 2006, he was Director, Biodiversity Information Services and a member of the Management Committee at the UNEP-World Conservation Monitoring Centre, in Cambridge, UK, where he represented the UN at international fora on biodiversity and biological research issues. Returning to Canada, he spent several years as Senior Advisor, Biodiversity, at AAFC, focusing on long-term maintenance of the Canadian National Collection (CANACOL) of insects and plants, before retiring in 2008. A published report, *Canadian Taxonomy: Exploring Biodiversity, Creating Opportunity*, grew out of his role as Member of the Expert Panel on the State and Trends of Biodiversity Sciences of the Council of Canadian Academies.

Peter is co-author (with Ross Layberry and Don Lafontaine) of the first truly comprehensive guide to Canadian butterflies, *The Butterflies of Canada* (1998), a seminal work that helped generate fresh interest in

Canadian butterflies by providing a means of identification for all Canadian species. Long before this publication, Peter was author, or co-author, of many other articles on butterflies. Of particular interest to an Ottawa audience is the article in the 1982 issue of *Trail & Landscape on Butterflies of the Ottawa District*, written with the same two co-authors noted above, and the 1996 *Checklist of Butterflies of the Ottawa District*. More recently, Peter authored a very essential report, *Sentinels on the Wing: The Status and Conservation of Butterflies in Canada* on behalf of NatureServe Canada. At present, he is working on a Royal Ontario Museum field guide to butterflies of Ontario, a publication eagerly awaited by many.

Peter continues his research on butterflies and their conservation, as an Honorary Research Associate at CANACOL, Agriculture and Agri-Food Canada, where he curates the Lepidoptera Collection. Furthermore, he is frequently called upon to give public lectures about various aspects of butterflies; in 2011, he was invited by the Toronto Entomologists' Association to give the inaugural lecture for the Quimby F. Hess annual lecture series. Peter spoke about butterfly conservation, population status, and how our butterflies can be protected.

In addition to Peter's many accomplishments in the world of Lepidoptera, he has also been intimately involved with The Ottawa Field-Naturalists' Club for over 30 years. He was a long-serving Associate Editor of *Trail & Landscape* (1981-1993). He has been a member of OFNC Council as well as various committees. He has led many club walks over the years, most recently summer excursions to look for butterflies in Larose Forest.

As well as the butterfly-focussed articles above, Peter has written on topics as varied as otters, mosquitoes, and the Central Experimental Farm, for *Trail & Landscape*. Peter has also published widely in journals as diverse as *Biodiversity: Journal of Life on Earth* and the *Canadian Journal of Zoology*.

One of the most enduring projects of the OFNC, the Fletcher Wildlife Garden, is the brainchild of Peter, who along with his wife, Judy, conceived the idea of a wildlife garden to celebrate Wildlife '87. As noted in a press release from the Canadian Wildlife Service at the time, "The focus of Wildlife '87 is on conservation of wildlife and its habitat." Peter took that theme

and flew with it, and by the summer of 1990, the Fletcher Wildlife Garden held its grand dedication ceremony, to which over 1,400 people came. The thriving garden is now a well-known entity amongst many in the city, and beyond. It is a fitting legacy for someone who has spent his life watching and protecting butterflies, for the garden has become a haven for a diversity of butterflies, as well as a myriad of other wildlife.

Member of the Year: Jay Fitzsimmons

The OFNC's Member of the Year award recognizes the member judged to have contributed the most to the club in the previous year.

This year we are recognizing Jay Fitzsimmons for his work managing the electronic publishing of the Canadian Field-Naturalist (CFN) and also for his enthusiastic and far-reaching promotion of the journal.

Jay joined the Publications Committee in 2009 and soon started championing an electronic version of the CFN. He was not only vocal about it; he was actually willing to do all the hard work to make it happen. In the fall of 2011 the first electronic issue of the CFN was published, Volume 125(1), and the CFN moved into a new era with Jay as the volunteer Journal Manager.

Being the journal manager for the CFN is a big job. With one hand he tracks renewals and money coming in for subscriptions and author charges. With his other hand he looks after all the technical issues of publishing online. At one point Jay realized that people using Internet Explorer were having difficulty with parts of the download. Another time he realized we needed to change servers, so he put together a proposal for Council to make it happened quickly. It is at least in part a testament to his beyond-the-call-of-duty efforts that there has been no decline in the number of CFN subscriptions during its transition to a predominantly electronic form.

However, Jay was not content to stay in the background keeping the machinery running. He has become one of the best promoters of the journal. At the 2012

Peter is also active with the Monarch Waystation at the garden, providing leadership and guidance for the project.

For all of these reasons, it is a pleasure and privilege to bestow upon Peter W. Hall, an Honorary Membership in the Ottawa Field-Naturalists' Club.

(Written by Christine Hanrahan)

Evolutionary Conference in Ottawa he teamed up with the Editor-in-Chief, Carolyn Callaghan, to make their presence felt. Banners were created and promotional postcards were handed out with a QR code linking to the CFN website. He created a Twitter account to tweet at the conference to get more followers. Post-it notes invited authors to publish their research with the CFN. Similarly, in the fall Jay represented the CFN at an Ontario entomological conference and equally promoted the journal.

Jay started a blog that linked to the CFN website to communicate with those interested in the evolution of the CFN. It is chatty, funny and very interesting. In it he gets excited when a new issue is being published and gives highlights of its contents. He explains any glitches in publishing. He helps draw scientists back to it by providing lists of related conferences and other blogs. The tone is up-beat and lively. In addition he continues the twitter account and monitors the impact of it on hits to the CFN webpage. No one could call the CFN stodgy.

In his "spare" time in 2012, Jay completed his PhD in the field of insect ecology, and became a Science Advisor for the Canadian Wildlife Service. On the home front he is married with two pre-school children to keep him busy.

Jay is one part technical manager, one part firefighter and several parts cheerleader. For all these reasons we want to recognize his efforts in 2012 to help the club's journal realize its full potential.

(Written by Ann MacKenzie)

George McGee Service Award: Constance Clark

The George McGee Service Award is given in recognition of a member who has contributed significantly to the smooth running of the Club over several years.

Connie Clark has been a member of the Ottawa Field-Naturalists' Club since 1988. She has been a volunteer at the Fletcher Wildlife Garden (FWG) since its inception. She has contributed articles to *Trail & Landscape*, has been a leader and co-leader of many outings and was a mainstay as the food co-ordinator for the annual Soirée for 6 years.

Her volunteering at Fletcher began in 1990. She was one of the first people to help plant trees in the New Woods area when it was still a grassy lawn in the very

early days of FWG. However, in those pre-retirement days, Connie was pretty busy with other activities, and it wasn't until 2003 that she came back to the FWG.

While Connie's interest is in the forests and woods, Marilyn Ward encouraged her to give the Back Yard Garden (BYG) work a try. She found it interesting, and it was the Woodland Walk section that convinced her to remain. With the treed ravine on one side, tall shrubs on the other and a remarkable diversity of native woodland plants flourishing along the short trail, she was hooked. She took over responsibility for the Woodland Walk the next year. She began working on other parts of the BYG, doing a little bit of everything. In her third

year she focused on the Heritage Bed and the Rockery. For several years she grew hundreds of plants from seed in her home in preparation for the annual FWG Plant Sale. She has been a member of the Friday morning group for 10 years, bringing her commitment, determination and quiet support to the BYG, contributing her time and energy to whatever needs doing. In addition she has staffed the OFNC booth created by Education and Publicity on several occasions.

Connie is a terrific all around naturalist. Her curiosity about the natural world led her to immerse herself in places like Algonquin Park for extended periods learning about, researching and studying everything that caught her eye. From 2005 to 2010 Connie was a member of the Excursions and Lectures Committee. During this period she organized and co-ordinated dozens of outings. She led or co-led 16 outings herself, introducing participants to many of the rich and accessible places to explore in the Ottawa area. While she focussed on flowers, ferns and fungi, Connie's broad knowledge of and interest in the natural world made her an extraordinary leader. She prepared thoroughly for every out-

ing, scouted out the conditions, made extensive notes and prepared presentations to introduce participants to the area of focus. She kept detailed written and photographic records of sightings on her outings and shared her field notes with participants, providing valuable knowledge regarding timing and location of her findings. Her articles about Monaghan Forest and Poison Ivy were published in *Trail & Landscape*, along with her poem, *There Have Been Days*.

In addition to her key role as co-ordinator of the food purchasing and preparation for the Soirée for several years, one year Connie prepared a nature quiz for the entertainment of attendees. She also wrote and performed nature themed songs.

The Club has benefited greatly from Connie's general knowledge, experience and botanical know-how. It is for her quiet, behind the scenes generosity of time and energy that we wish to honour Connie with the George McGee Service Award for 2012.

*(Written by Julia Cipriani
with input from Christine Hanrahan)*

Conservation Award – Member: David Seburn

The Conservation Award for a member is given in recognition of an outstanding contribution by a member in the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

David Seburn is an independent researcher specializing in the conservation of amphibians and reptiles, particularly turtles. This award recognizes David's significant efforts for over a decade in turtle research and conservation in the Ottawa area.

Work on turtles is crucial, as seven of Ontario's eight turtle species are on the Species at Risk in Ontario List. Threats include habitat loss and fragmentation, road mortality, persecution, illegal collection for the pet trade and pollution.

In 2011-12, David did yeoman's service as a diligent local advocate for the campaign to get the Ontario government to protect Snapping Turtles from hunting. Although the campaign was not successful, local efforts such as David's help to highlight the issue and raise awareness for OFNC members by providing information and advocating for change. David has also been involved in the OFNC's advocacy efforts to influence the City of Ottawa to promote conservation of Blanding's Turtles threatened by the Terry Fox Drive/South March development.

David's research and monitoring of turtles in the Ottawa region has produced significant results. For example, surveys he conducted of Spotted Turtles – an endangered species — at a site in eastern Ontario resulted in the site being acquired by the Nature Conservancy of Canada. David has also been conducting population monitoring of Spotted Turtles at another site in the

Ottawa area since 1999, building on a previous researcher's 1980's work, and resulting in an impressive 30 year data set for this project. David's work has included tracking individual turtles using radio transmitters, which has demonstrated that some turtle populations may be relatively immune to the threat of traffic mortality if they remain within large wetlands. This result provides the scientific basis for putting a conservation priority on the identification and protection of such sites.

David also undertook a study to identify Blanding's Turtle habitat use during hibernation at a site in eastern Ontario, and the results of this study are published in *The Canadian Field-Naturalist* (2010). He also wrote a conservation assessment for Blanding's Turtle in 2002. Blanding's Turtles have been a hot topic in the ongoing fight against developing the South March Highlands in Kanata.

David tirelessly promotes turtle conservation through presentations to groups such as naturalists, conservation professionals and even water garden enthusiasts, covering topics such as Ontario's turtles, population trends of turtle species in the Ottawa area and how to make your water garden turtle-friendly. David has also provided training on turtles to conservation partners, written general articles for the public ("help a turtle cross the road"), and participated on the Ontario Multi-Species Turtles at Risk Recovery Team when it was active. David is currently the Ottawa area regional co-ordinator for the Ontario Reptile and Amphibian Atlas.

The Club has truly benefitted from David's membership. He is not only active in the Conservation Committee but he and his family are active in the Macoun

Field Club for young naturalists, helping to pass his conservation knowledge and ethic to the next generation.

For his many contributions to turtle conservation in the Ottawa area and more broadly, the OFNC is pleased

to present David Seburn with the Conservation Award for a Member for 2012.

(Written by Eleanor Zurbrigg)

Conservation Award – Non-Member: Biodiversity Conservancy International and National Capital Commission

The Conservation Award for a non-member is given in recognition of an outstanding contribution by a non-member in the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

This year the award goes to Biodiversity Conservancy International (BCI) for the “National Capital Greenbelt Sand Dune Conservation Project” at the Pinhey Sand Dune and its partner the National Capital Commission.

The initiative began with the realization that the Pinhey dune, located off Slack Road, between Woodroffe Avenue and Merivale Road, was going to disappear. This is a unique habitat of dry, open, inland sand deposits not directly associated with rivers or lakes. The specialized flora and fauna found in these areas include provincially and regionally rare species.

The dunes were formed on the edges of the early postglacial Champlain Sea approximately 8,000 years ago. Over the past 60 to 70 years in eastern Ontario, the dunes have declined to only one per cent of their natural coverage. Trees, invasive shrubs, urban sprawl and the cessation of fire were all contributing to the loss of this unique habitat.

Of particular interest and concern is the ghost tiger beetle – a 12-millimetre long insect the same colour as the fine-grained sand and whose only home in Ottawa is the dunes on Slack Road. The beetles are not the only insects in this extreme environment. There are also Ant Lions which dig pits to trap ants.

In 2011, Biodiversity Conservancy International, a local scientific non-governmental organization, took the lead. Pete Dang and Henri Goulet went to the Trillium foundation and got \$10,000 in June 2011 to restore and expand the dunes over the next two years. Next they approached Eva Katic at the National Capital Commission who quickly became an enthusiastic supporter.

The organizing committee consisted of Pete Dang, Project Director, Stephen Aitken, Project Coordinator, Henri Goulet, Biodiversity Assessment, Joanne Hakkaku, Community Engagement and Volunteer Coordinator, Nina Edson, Volunteer Recruitment, Andrew Mott, Field Operation, TD Trinh, Logistics and Team Coordinator and John Davidson, Communications.

By the late summer of 2012 considerable work had been done along with a major education effort. Working with many community volunteers they were successful in opening up an area of the dune by removing small trees and buckthorn shrubs by hand, using shovels and spades. The group worked with aerial images of the area over the last 75 years to track some of the damage, then removed plants, weeds and trees to reclaim some of the habitat.

As the restoration process continued in the fall of 2012, the NCC provided heavy equipment to cut trees and dig out stumps to remove encroaching vegetation. When they were finished an area of over four times the original sand area was opened.

One of the mandates of the initial funding was to establish a mechanism to conserve the restoration accomplished by the project. In October, 2012, BCI created Stewards of Sand Dunes (SOS-Dunes) as the permanent steward of the sand dune system in Ottawa.

Now that the dunes have been restored to some of their former glory, the BCI – SOS-Dunes acting as stewards, and the National Capital Commission as the property owners, will work together as caretakers to protect the habitat and to educate the public with signage about the ecology.

This is a wonderful example of community-based conservation which brought a diverse group of people together.

*(Prepared by Ann MacKenzie,
based on material from Paul Catling)*

Anne Hanes Natural History Award: Diane Lepage

The Anne Hanes Natural History Award recognizes outstanding contributions of an amateur naturalist to our understanding and knowledge of the natural history of the National Capital Region.

This year, the worthy recipient is Diane Lepage.

Moths are considered by some to be the “poor sisters” of the more widely appreciated butterflies. Not so for Diane Lepage, who has made the study of moths her special passion. She is not only interested in the spec-

tacular, brightly coloured types like the huge silk moths that are familiar to most naturalists, but also the much smaller, mostly nocturnal species aptly named “micro-moths,” of which there are hundreds. It requires special techniques to discover these creatures, involving ultraviolet lights, long nights in the woods or along roadsides, and ways of documenting what you find. For many entomologists, this means a killing jar and long hours spent spreading wings and writing labels.

In Diane's case, the documentation is the non-lethal method of photography (in almost all cases). Several years ago, she gave a fully illustrated talk on moths to the Ottawa Entomology Club.

In the March 2013 issue of *Trail & Landscape*, Diane summarized five years of moth study at the Larose Forest, an ecological reserve 45 minutes east of Ottawa. In a lively and well-written article illustrated with her beautiful black-and-white photographs, she explains the importance of moths, something about their natural habitats and life histories, explains their taxonomy, and gives hints for observing them. This is followed by an astounding list of the 351 species she discovered, complete with scientific and vernacular names. This would make the Larose Forest one of the most intensely studied areas of eastern Canada for the moth fauna. Diane notes that every time she returns to the Forest, she encounters new species for her list, and so it is clear that many more species remain to be discovered.

Diane has not only looked at the moths of Larose Forest. Her observations have been made throughout the Ottawa Region and sometimes beyond. She has led well-attended OFNC evening excursions to share the

experience of seeing night-flying insects with other Club members. She is a frequent participant in Bio-Blitzes in the region, also adding to our knowledge of the moth fauna. Professional entomologists, such as Dr. Don Lafontaine at Agriculture Canada's insect collection, regard Diane as great source of information, and she is acknowledged by them as an expert on the moths of eastern Ontario and western Quebec. Her donations of interesting and significant moth specimens to the National Collection are highly valued and appreciated.

Not surprisingly, Diane is also interested in butterflies, and she is one of the leaders of the annual Butterfly Count. Her tireless work at the Fletcher Wildlife Garden's Butterfly Garden resulted in her being given the Member of the Year Award for 2008.

Diane's work is an excellent example of what a dedicated and knowledgeable amateur can achieve in making lasting scientific contributions. This is precisely the kind of individual that merits the Anne Hanes Natural History Award, and it is with great pleasure that we award it to Diane Lepage this year.

(Written by Irwin Brodo)

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